Journal and Proceedings

OF

The Royal Society of Western Australia.

PATRON: HIS MAJESTY THE KING.

Volume VII.

1920 - 1921.

The Authors of Papers are alone responsible for the statements made and the opinions expressed therein.

PRICE: Five Shillings.

Perth:

BY AUTHORITY: FRED. WM. SIMPSON, GOVERNMENT PRINTER.

1921.

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LIST OF OFFICERS, 1220-1921.

Patron: His Majesty the King.
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1918–19—W. J. Hancock, M. Inst., C.E., M.I.E.E.
1919–20—G. L. Sutton.
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Postal Address and place of meeting—
The Museum,
Beaufort Street, Perth, W.A.

PROCEEDINGS OF THE ROYAL SOCIETY OF WESTERN AUSTRALIA.

August 10, 1920.—The President, Dr. E. S. Simpson, in the Chair. Mr. G. L. Sutton delivered the Presidential Address on "*Science and Agriculture,*" and stressed Western Australia's opportunity for post-war development of her agricultural resources. Messrs. M. Aurousseau, B.Sc., and S. A. Budge, B.Sc., presented a paper on "*Terraces of the Swan and Helena Rivers and their Bearing on recent Displacement of the Strand Line.*" Mr. L. Glauert read a paper on *Western Australian Petrels and Albatrosses.*

September 14, 1920.—The President, Dr. E. S. Simpson in the Chair. Mr. L. Glauert, F.G.S., read a paper on "*Fishes collected by the State Trawler 'Penguin' east of Albany.*" Mr. H. Bowley read a paper on "*Contributions to the Chemistry of Alunite.*" Mr. D. A. Herbert read a paper on "*Contributions to the Flora of Western Australia.*" Captain McVicker Smyth exhibited specimens of crystalline gold from Payne's Find and extended to the Society an invitation to inspect his collection at some future date.

September 21, 1920.—At the invitation of the President, Captain Ault of the "Carnegie" gave a lecture to a special meeting on the work being done in the magnetic survey of the seas.

October 13, 1920.—The President, Dr. E. S. Simpson in the Chair. Mr. H. B. Curlewis read a paper on "*Tides on the Western Australian Coast and on the Swan River,*" illustrating it by lantern slides and graphs. In the ensuing discussion attention was drawn to the marked local effects of the South Perth ferry boats.

November 9, 1920.—The President, Dr. E. S. Simpson in the Chair. Mr. L. Glauert, F.G.S., exhibited a red-necked avoset and a ringed snake six inches long which had died while attempting to swallow a 4½-inch lizard. Mr. A. Montgomery gave an account of the Yampi Sound Iron Ore which contained 69·6 per cent. iron, and which has recently been purchased by the Queensland Government. Dr. E. S. Simpson read a paper on "*Staurolite from the Mogumber District.*" Dr. Simpson drew the Society's attention to the presence of Prickly Pear at South Perth; the discussion was postponed till the December meeting.

December 14, 1920.—The Vice-President, Mr. F. E. Allum, in the Chair. Messrs. L. W. Phillips, B.Sc., and C. A. Gardner were elected ordinary members. The discussion on Prickly Pear was re-opened. Mr. D. A. Herbert pointed out that the pear had

been present in the State for a great number of years, and was not likely to spread, nor was it the species which was most troublesome in Queensland and New South Wales. Mr. Shelton exhibited photographs of prickly pear fruiting at Busselton. Mr. G. L. Sutton exhibited some varieties of wheat giving high yields in England but which could not be expected to be so successful in Western Australia. Mr. Glauert exhibited a mounted specimen of a saw-shark (*Pristiophorus*, sp.) Mr. Herbert made some remarks on a specimen of Blackfellow's Bread (*Polyporus Mylittae*) which Mr. W. C. Grasby had obtained from Nannup. Mr. Herbert read papers on "*The Genus Xanthorrhœa in Western Australia*," "*Parasitism of the Quandong* (*Fusanus acuminatus*)" and "*Parasitism of the Sandalwood* (*Fusanus spicatus*)" the last-named being in conjunction with Mr. C. A. Gardner.

March 8, 1921.—The President, Dr. E. S. Simpson in the Chair. Mr. D. A. Herbert exhibited a new species, *Thryptomene fimbriata*, from Dowerin. Mr. L. Glauert read papers on "*A Synopsis of the Fossil Monotremes and Marsupials of Australia*," and "*Pleistocene Fossil Vertebrates from the Fitzroy River*." Mr. L. Glauert and Mr. J. Clark were chosen to represent the Society at the forthcoming vermin conference. On the motion of Mr. Clark it was decided that the authorities should be communicated with in regard to the preservation of the Stirling Range for fauna and flora. It was pointed out that a great deal of destruction to the bush was being done through pastoralists' fires. Mr. Glauert drew attention to the scarcity of animal life as shown by the results of the recent Museum expedition to the Range.

April 8, 1921. The Vice-President, Mr. F. E. Allum in the Chair. Mr. Glauert gave an account of the results of the vermin conference and announced that both the Society's representatives had been appointed to a committee to carry on the work. Mr. Herbert exhibited specimens of some plant diseases new to Western Australia. Sunflower Rust (*Puccinia helianthi*), Couch Grass Smut (*Ustilago cynodontis*) and Root Gall of the Apple (*Bacillus tumifaciens*).

May 10, 1921.—The Vice-President, Mr. F. E. Allum in the Chair. Mr. W. B. Alexander, the late Hon. Secretary, was elected a Corresponding Member. Professor Nicholls was elected an ordinary member. Mr. Glauert exhibited a specimen of an Isopod from a leatherjacket, a Portuguese Man-of-War (*Physalia*, sp.) from Cottesloe, and a Gummy (*Mustelus antarcticus*). Mr. Herbert exhibited specimens of *Argemone Mexicana*, the Prickly Poppy, from Beverley, and the haustorea of seven santalaceous plants hitherto uninvestigated. Professor Nicholls read a paper on *Dero roseola* recording it for the first time from Western Australia. Mr. A. Montgomery gave an address on pulverization of coal.

June 13, 1921.—The President, Dr. E. S. Simpson, in the Chair. The date of the annual conversazione was fixed for Saturday, July 23rd, and a committee of ladies was appointed. Mr. Herbert read a paper entitled "*Contributions (No. 3) to the flora of Western Australia.*" Mr. W. E. Shelton read a paper on "*Xerophytism in the Swan River District,*" illustrating it with lantern slides and microscope sections. Mr. Glauert read papers on "*Variations in the Permanent Premolar and a description of the Deciduous Premolar of Nototherium Mitchelli,*" and exhibited specimens of the Bill fish and the Indian Jungle Fowl (*Gallus sonnerati*). Mr. Herbert moved and Mr. Clark seconded that a message of congratulation be sent to Mr. Sutton on his recent appointment as Director of Agriculture, and the motion was agreed to unanimously.

THE JOURNAL

OF

THE ROYAL SOCIETY

OF

WESTERN AUSTRALIA.

VOL. VII.

Presidential Address.

SCIENCE AND THE MINERAL INDUSTRY.

Presidential Address by E. S. Simpson, D.Sc. (delivered on 11th July, 1921).

One of the most important lessons which the Great War has taught the peoples of the world is that self-preservation requires each nation in time of stress to be self-contained, not only in the matter of food supplies, but in supplies of all those various substances which form the basis of industries, particularly of key industries. Australia has for many generations been content to import from abroad, mainly by long sea routes, not only essential supplies which cannot be produced at all, or at any rate not readily on the spot, but also innumerable things which are found abundantly in her own domain, or could be manufactured from her own raw materials. We are led therefore to enquire is Australia securely self-contained in the matter of essential supplies, or is she condemned for ever to rely upon importation and storage against emergencies. This suggests the urgency of a scientific stock taking, in the greatest detail, of our natural resources and manufacturing capacity.

Let us take another standpoint. The last twelve months have witnessed a veritable collapse in all branches of our mineral industry with the exception of coal mining. The gold industry of this State in particular has dropped to about one-fourth of its magnitude of a few years ago, and the whole mineral industry in the State seems on the down grade, whilst all the largest base metal

mines in the Eastern States are closed down. Though this is due in part to new conditions which are outside the scope of the scientist, there are still many factors involved with which the scientist is alone equipped to deal. There certainly seems much that may be done to defer the closing of the fatal scissors formed of the converging lines of grade of ore and cost of treatment.

Taking as axioms that knowledge is power, and that ordered knowledge is the domain of the scientist, the two considerations that I have detailed offer abundant scope to the scientist in (Western) Australia, in the direction of sustaining and improving a flagging industry, whilst at the same time rendering our land during times of peace more secure in future times of stress.

The work that has been done during the present generation by our geologists in Australia is a monument to the value of geological science to all branches of the community. This work has received wide publicity and earned a large measure of popular recognition. For these reasons I do not intend to deal with it to-night, but shall confine myself rather to the position of the mineral and industrial chemist and physicist in relation to the mineral industry. In passing one might, however, be permitted to point out the great utility and urgency of an accurate definition by our geologists of the regional distribution of all the economic minerals.

Except indirectly through the engineer and metallurgist, the physicist has not come closely into contact with our mineral industry. For the metallurgical physicist there is still much to be done in the study of the effects of varying heat treatment upon the physical properties of simple metals and alloys, a thorough understanding of which would certainly tend to reduce the cost and widen the utilisation of these mineral products. For many generations there has been a widespread belief in the theory that ore deposits and underground water channels cause a local modification of the magnetic elements, a fact of the highest importance in prospecting if it should prove to be so. In the past the lack of detailed magnetic surveys has been a bar to any proper scientific investigation of this theory, and various charlatans and self-deluded persons have played on the credulity of the public and wasted capital and labour on the supposed evidence of various simple or complex instruments said to be capable of detecting ore, water, or petroleum at depths up to several thousands of feet. Now that the Carnegie Institute is well advanced with its magnetic survey and has chosen Western Australia as one of its first spheres of action, there is room for physicists to test this still doubtful theory, and to incidentally settle once for all, in a manner which will admit of no question, the value or otherwise of the many forms of mineral detectors, ranging from divining rods to complex instruments quoted at prices running into hundreds of pounds.

Of prime importance to this and every other country is the early compilation of a complete census of our mineral resources, whether the matter is viewed from the point of view of national safety, or of facility of mineral production or of economy of manufacture. The foundations of this have been laid by our Geological Survey during the past 25 years. It is only, however, the foundations that have been laid, and the completion of the stocktaking will tax for many years to come the energies of all our available geologists, chemists, physicists and quantity surveyors. Such a stocktaking can never be finalised as new discoveries are made from year to year, but only when it is completed right up to date will we be in a position to meet all national emergencies, and to manufacture essential mineral products in successful competition with foreign rivals.

Questions of organisation and administration are not usually looked upon amongst us as lying within the ambit of the scientist, though rightly I think, so considered by our cousins of the United States. The present organisation of our mine staffs certainly deserves careful thought. The prime objects of a mining engineer are to detect and follow ore bodies and to exploit and bring the ore to the surface. It is for these duties that he receives a long and careful education, and if through any cause he is compelled to neglect these duties, they are imperfectly and uneconomically carried out by someone less efficient in this particular direction. Too often these days a mine manager's time and thought are expended on labour troubles, or preparing evidence and attending arbitration courts. This is surely not as it should be, for under these conditions the mining engineers' special technical knowledge is being lost to the mine he controls, with a disastrous effect upon the life and economic productiveness of the property. The possibility of groups of mines employing collectively labour and arbitration experts, leaving their engineering staffs free to concentrate their energies on engineering problems, seems worthy of consideration as one method of dealing with the existing unsatisfactory condition of affairs.

Let us consider some aspects of the relationship of the chemist to the mineral industry. One should bear in mind from the outset that Nature herself is the super chemist, with her mighty workshops and ceaseless activity through countless ages. Very little consideration will lead us to realise that all man's activities are ultimately dependent upon the continued supply by nature at the earth's surface of crude mineral matter of suitable kind for the use of living organisms. To-night we are specially concerned with the necessary supply to mankind of the minerals, metals and inorganic salts, which form the basis of the mineral industry, and which in times of peace our modern civilisation is demanding yearly at a rapidly increasing rate, and which in times of war are essential to our national defence.

The ultimate source of all our supplies of the valuable metals is the magma or molten rock of the primeval surface of the globe. No one has positively identified any mass of this magma in either still fluid or congealed form, but a study of the visible products of its alteration enables us to arrive at a very fair estimate, though admittedly not a rigid one, of the quantities of those valuable constituents which were presumably more or less homogeneously distributed through the primeval magma. On the basis of the numerous rock analyses which have been made all over the world, and upon calculations of the relative quantities of the different rocks disclosed at and near the surface, estimates have been made from time to time of the average quantities of the various elements distributed through that comparatively thin crustal portion of the globe, the so-called "lithosphere," which is within reach of living organisms and man in particular. These estimates are rather startling at first sight, since they show that out of 83 known elements the majority of which has become indispensable to us, two, viz., oxygen and silicon, together monopolise 75 per cent. of the whole earth's crust. Only six others are present to the extent of between one and ten per cent., viz., aluminium, iron, calcium, magnesium, sodium and potassium ; and three others, titanium, phosphorus and hydrogen are present to the extent exceeding one part in one thousand. Of the remaining 72 elements, several like carbon absolutely essential to life, 11 are present in quantities less than one part in one thousand, whilst others equally essential to our present day machine-made civilisation, such as copper, the other heavy metals, iodine or arsenic, were distributed on the whole through the crustal magma only in minute proportions amounting to less than one part in ten thousand, or in such a proportion as would utterly prohibit our collection of them in suitable quantities to supply our present day necessities, were they to have remained thus evenly distributed.

Fortunately for us nature is above all the great concentrator of her own widely dispersed wealth, this concentration being dependent to some extent upon purely physical and mechanical processes, but in the main upon chemical processes which it behoves the chemist of the present day to study closely, lest mankind, having rifled to exhaustion the more obvious and easily accessible of nature's storehouses, shall find itself without the knowledge which will enable it to maintain its sources of essential supplies.

Geochemistry, the chemistry of the earth's crust, is not by any means a new science, though its name is somewhat new, but it is a science which has been greatly neglected in most civilised countries. The birth of geochemistry was in fact coincident with the birth of the sciences of chemistry and mineralogy, since amongst the first substances to be subjected to chemical analysis were some of the commoner minerals, and in still earlier times manufactures

had been built up which depended upon the accidentally discovered, unsystematised and limited knowledge of the chemistry of certain mineral compounds.

It is unfortunately, however, a fact that in spite of the importance of the mineral industry and the large number of people employed in it, the science of geochemistry has not advanced to anything like the extent that its sister sciences have done. Mineralogists have concentrated their attention too greatly upon physical characters, which are rarely of importance in the practical utilisation of minerals. The chemical properties of minerals have been the subject of comparatively little research, such work as has been done in this field being for the most part the mere piling up of innumerable analyses of simple minerals, and of those common mineral aggregates which we know as rocks and metallic ores. It is only in recent years and in a minority of cases that these analyses have been done with that completeness and exactitude which modern theoretical science demands as the basis of its generalisations, and modern industry demands as a basis of its processes. Now whilst it is very necessary to make and record mineral analyses and rock analyses, particularly from new regions, these are after all only the rough unshapen stones of which the edifice of this science is to be built. If the science is to be of any direct benefit to mankind, as it can and must be in ways which I hope in some measure to indicate to you, something very much more is required of its devotees than the mere multiplication of rock and mineral analyses.

The subject of mineral, genesis including the origin of ore deposits in which term are included those natural concentrations of all minerals of economic value to civilised man—requires the closest attention of the scientific world at the present juncture. These problems involve the application of certain physical and mechanical principles, but are essentially chemical ones, and ones the solution of which are likely to lead to the most valuable economic application, besides enlarging the boundaries of our knowledge of pure science. The discovery of the exact cause of a disease is a big step in the direction of combating it, and similarly the discovery of the exact source and mode of formation of a mineral must prove a big step in the direction of finding and following workable deposits of it. This is one way in which the study of geochemistry should yield a rich reward to the successful investigator, and galvanise the mineral industry into fresh vigour.

What are the origins of the many, but by no means innumerable, storehouses of nature's chemical concentrates ? When we have exhausted the more obvious of these, where are we to search for others that our civilisation may not be brought to a standstill ? The answers to these two questions will be found in the main by the application of chemical principles. In the earliest days of his

existence upon the earth man only benefited by those elements which were widely and more or less evenly distributed throughout the earth's immediate surface, or was led by blind chance to concentrations of those others which his growing knowledge led him to look upon as indispensable. As time went on an exhaustion of some of the widely distributed elements was already apparent, the local exhaustion of phosphorus in the soil for instance, and man became more than ever dependent upon natural concentrations and upon his purely chance discovery of them. First to his aid came a glimmering of the relationship between ore deposits and physiographical and geostructural features. Last, and to an imperfect extent, geochemical principles are being, and must continue to be, developed to guide him in his search. Some few broad geochemical ideas are of common knowledge, and often unconsciously applied. Such for example as that chromite (chrome ore) is invariably associated with rocks of a definite chemical type, viz., the so-called ultra-basic rocks: that galena and silver minerals are almost always found together in genetic relationship: that pyrites and gold are not uncommonly co-precipitated in nature: that commercial felspar is never found anywhere but in the products of consolidation of acid, *i.e.*, persilicic magmas. A few such truths are widely known and freely made use of in practical mining, but little appreciation is yet shown of the fact that other similar genetic relations of a chemical nature are fairly well established and many others must be awaiting discovery, with equal possibilities of practical application in the two branches of mining, viz., prospecting, or the detection of new masses of ore, and exploitation, or the following up and bringing to the surface of the whole valuable portion of a known mass.

Your attention has already been drawn to the fact that in Western Australia mining has reached a stage of serious decline, which has already reacted deleteriously upon the whole community and can only be remedied in one of two ways, viz., by the early discovery of new mineral deposits equally profitable to those which have been worked in the past, or by the reduction of the cost of working those known deposits to such an extent as to widen considerably the limits of payable ore. Science can render aid in both directions.

Sir William Crooks, in his Presidential Address to the British Association in 1898, was the first to sound the ominous note of Famine in regard to mineral supplies necessary for our existence. In this notable address he pointed out the absolute dependence of man on a sufficiency of nitrogenous food, and the impossibility of producing this without an unfailing and indeed increasing supply of soluble nitrates or ammonia salts. At the same time statistics proved that our then known natural sources of both, viz., the mineral nitrates of Chili and India, and the coals of known and strictly

limited coal fields, were diminishing at a rapid rate. In this case the chemist, physicist and engineer have already come to the rescue of mankind, and the economic conversion into fertilising salts on a large scale of the unlimited and ever renewed supply of atmospheric nitrogen is a tangible proof of the success of their endeavours.

The nitrogen famine is a bogey of the past, but local Australian famines, *e.g.*, in potash, mercury and platinum are only too apparent in times of emergency, and a shortage of gold is not by any means unlikely in the near future. We have therefore reached a stage in the world's history when the geochemist and geophysicist are increasingly important members of the community.

Our gold yield is steadily decreasing and with it one of our greatest sources of wealth. Every month we hear of mines being closed down because the working expenses, and value of ore in sight, factors which have been steadily converging during recent years, have at last reached the same level and passed beyond it. Can the scientist be of any service in remedying this? I unhesitatingly answer, yes. One direction in which the chemist can help I shall deal with more fully later, viz., in devising cheaper methods of extraction, using chemical processes and reagents less expensive than those now used. I wish to consider an entirely different line of assistance, one that has been less studied by chemists, and one therefore which offers more scope and greater chances of obtaining successful results. I refer to the assistance which can be given to prospecting, using the term to cover not only the detection of quite new concentrations of gold, but the tracing of the entire course of those already disclosed. At present through a grievous lack of scientific knowledge, both phases are largely directed by the ruinously expensive process of "blind stabbing," the chance opening of prospecting shafts, drives and bores, guided only by imperfectly understood laws of geological structure and mechanical fissuring. Although these factors have considerable influence on the position and form of ore-deposits, the preponderating influence is chemical, being a matter of solubilities, ionisation, hydrolysis, oxidation, reduction, double decomposition, mass action and reversibility of reactions under variations of temperature and pressure.

To the majority of persons actively engaged in our primary mineral industries many of these terms are meaningless. It is doubtful if any of them could apply them at present with any practical effect to the problem of reducing the cost of searching for continued supplies of payable ore. For this the chemist himself is mainly to blame, for except in the domain of secondary enrichment, chemical investigation in the field of ore deposits has been comparatively meagre and unsystematic.

It should not therefore be labour lost to bring before the scientists of this State, which has owed so much in the past to a

now languishing gold industry, an outline of the main principles concerned in the formation of ore deposits, particularly of gold deposits.

I have already indicated to you the widely scattered nature of our original elemental supplies and their low concentration, with very few exceptions, in the great mass of the earth's crust. What are the nature and origin of the concentrations upon which we must depend for our industrial supplies ? Of the three components of the outer accessible portion of the earth, the atmosphere will yield us only oxygen, nitrogen and water amongst all the many elements and simple compounds we require. The second great crustal division, the ocean and lakes, or hydrosphere, now yield and will continue to yield us, in addition to water, sodium and chlorine, and possibly in the future potassium, which it contains to the extent of four parts in ten thousand. It is evident that it is on the lithosphere, or solid crust of the earth, that the chemist is, and will be, dependent for most of his material, whether he is engaged upon purely scientific investigations or on industrial manufacture. To appreciate the facts and problems of ore deposition some knowledge of the earth's crust is essential.

The modern geologist has used a chemical basis for his division of the lithosphere into several concentric zones and belts. The upper zone or zone of katamorphism, is characterised by exothermal reactions and by the preponderating formation of simple compounds from more complex ones. It is divided into two "belts," the upper "belt of weathering" in which aqueous solution, oxidation and carbonation are the most prominent features : the lower "belt of cementation" in which hydration of pre-existing compounds and filling of spaces by deposition from solution are predominant.

At a depth of approximately 10,000 metres begins the second great zone of the lithosphere, the "zone of anamorphism," characterised by the predominance of endothermal reactions, particularly silication and dehydration, and by the building up of complex molecules from simpler ones. Under the enormous pressure existing at this depth all known mineral masses are plastic, and therefore cavities, other than subcapillary ones, must be absent.

Beneath the zone of anamorphism and at times bursting through both this and the overlying zones, is the zone of actual or potential fluidity, actual probably only under local conditions of reduced pressure.

Beneath this again is the "barysphere." The average density of the whole earth as determined by astronomical methods is 5·6, whilst the average density of the lithosphere, *i.e.*, the top 10 miles of the solid crust, is given by competent authorities at 2·7. We must therefore assume that below the lithosphere there is a barysphere, *i.e.*, a mass of minerals with high specific gravity. The

only minerals we can conceive of this nature are those containing a large proportion of the heavy metals, such mineral in fact as would, when found within reach of man, be considered as metallic ores.

Having thus briefly considered the various zones of the upper portions of the earth we are in a position to consider the theory of origin of the more important of those primary subsurface concentrations of metallic ores which we call ore deposits, and which supply us with all our heavy metals, particularly, so far as we are concerned, with gold.

In the 80's and 90's of the last century two rival schools of thought as to the origin of these metalliferous ores waged a wordy warfare. The rival theories were those of "lateral secretion" and "ascension." The supporters of the former theory urged that these metallic ore deposits were precipitates in fissures or other cavities from solutions which seeped laterally into them from the walls immediately adjacent. That these solutions were aqueous solutions of metals derived from the widely distributed but minute amount of metals occurring in the surrounding rocks flanking the deposit. The bases of this theory were the known and assumed movements of water underground and the many determinations by Forschammer and Sandberger of the presence of traces of heavy metals in the rocks, and rock forming minerals of mining districts. Apart from the fact that it is just as probable that such traces may have been distributed from the vein into the surrounding rocks, as that the reverse movement took place, there is considerable doubt attaching to several of these determinations, particularly with regard to the methods used for the estimation of minute amounts of gold, silver, and zinc, many of the determinations of these being now looked upon with grave suspicion.

The supporters of the now generally accepted theory of "ascension" consider that all the valuable constituents of primary ore deposits were brought into their present position in solution or as vapours from considerable depths within the zone of fluidity or the underlying barysphere. Ore deposits are notoriously associated with intrusive rocks, which are known to carry much water and small amounts of heavy metals. During the consolidation of such rocks from fluidity, a chemical process goes on akin to that which takes place in the concentration of sea water. Large amounts of the most abundant components first crystallise out, leaving towards the end of the process a "brine" in which are concentrated the valuable metallic constituents in the form of soluble salts and ions in solution in the residual water, which finds its way into adjacent and overlying fissures and cavities and often by energetic chemical action dissolves spaces in surrounding rocks and precipitates in these spaces new minerals partly of economic value.

The composition of these original metalliferous solutions and the precipitation of the metals from them during their migration, by changes in temperature and pressure, by interaction with other solutions derived from elsewhere, or by interaction with the solid minerals with which they come in contact, all these are matters demanding the closest study. Only when they are thoroughly investigated and understood will the present unscientific and wasteful methods of prospecting and development give place to thoroughly scientific and therefore economical methods.

One of the earliest theories of the origin of gold deposits, and one which still prevails almost universally is that the gold was originally a very minor constituent of a molten magma, the solidification of which resulted in a concentration of practically the whole of the metal in the form of gold chloride in a comparatively small volume of water. This solution rising under pressure into cavities in the zone of anamorphism and katamorphism met there with reducing agents, particularly with the carbon of fossil vegetable matter, which produced a separation of the metal. If this be so the richer portion of the gold deposit should be found adjacent to carbonaceous portions of the wall rocks, and the worthless portions of a gold deposit adjacent to those portions lacking in carbon. This theory appears to be borne out by facts in some few cases, *e.g.*, at Bendigo, and has resulted in a scientific direction of prospecting operations in certain districts.

The study, however, of the majority of Western Australian gold deposits, and of many in other parts of the world, shows this theory to be completely inapplicable in the majority of cases. In a description of the Kalgoorlie deposits published in 1912, I first promulgated the theory that the gold in the primary solutions of magmatic origin was present not in the form of chloride but in the form of the sulphaurate anion, (AuS_2). Simultaneously and independently a similar suggestion was put forward by Professor Lenher of California to explain the primary introduction of gold into some of the rich veins of that State. The main facts upon which this theory was based by myself are briefly :—

1. The invariable association of free gold and pyrite and the very frequent quantitative substitution of the latter for previously existing iron silicates :
2. The association at Kalgoorlie, Ora Banda and elsewhere of free gold with tellurides of gold, silver, and other metals soluble as sulphosalts :
3. The frequent absence of any concentration of gold in the immediate neighbourhood of bands of graphitic material, whilst the contrary would be the case if gold had arrived in the form of solutions of auric chloride and auric cation ;

4. The frequent presence of secondary potash minerals, chiefly muscovite, in auriferous metasomatic lodes, this potash being largely in excess of that in the original rock :
5. The frequent enrichment of gold veins, *e.g.*, at Lennonville, at the intersections with previously existing bands of haematite (ferric oxide), a moderately strong oxidising agent :
6. The occasional intimate association of gold with other strongly oxidising agents, for example, with manganese dioxide at Kanowna, and with chromium compounds at Westonia.

These six conditions associated with enhanced gold precipitation do not appear to be compatible with the theory of the introduction of gold in the form of solutions of auric chloride and auric cation, whilst they are intelligible with the theory of the introduction of gold in magmatic waters carrying potassium sulphaurate and free sulphaurate anion.

The purely chemical aspect of the genesis of gold in our primary gold deposits is one which is in urgent need of investigation, and I think you will agree with me that the solution of this problem cannot but have a very important bearing upon the prospecting and exploiting of such deposits both in Western Australia and elsewhere.

In quite a different direction altogether the mineral chemist is destined to play a large part in the near future. Up till now, thanks to nature's industry, we have been enabled to obtain sufficiently large supplies for our necessities of such minerals as are usually adapted to manufacturing processes. In consequence, a very superficial and incomplete knowledge of the chemistry of minerals has enabled us to keep the world supplied with all its needs of soluble potash and phosphorus salts, of metallic aluminium, copper and iron, and so on. The war has already proved to us the grave danger of relying too completely upon a single source of any essential mineral product, and the rapid exhaustion of high grade crude minerals all the world over will compel us to a closer chemical study of the lower grade minerals upon which we are destined to become more and more dependent.

As an example of what scientific assistance can be given in this direction let us consider the position in relation to potash supplies created by the war. The Germans have been favoured by Nature with an immense supply of high grade and easily treated potash minerals. Because of this they had by 1914 monopolised the whole potash supply of the world. The cutting off of this supply created a potash famine in Australia, affecting many industries but particularly fruit and potato growing. To relieve

the situation two courses were open to us, either to discover in Australia a supply of easily utilised salts of the German type or to locate other potash minerals and devise means for their economic utilisation.

To the monumental work of several scientists, particularly J. Usiglio, C. Ochsenius and J. H. Van't Hoff, is due the thorough understanding of the origin of the famous German potash deposits through the evaporation under normal conditions of temperature and pressure of a completely or almost completely land locked mass of ocean water. The complete details of the whole process have been so thoroughly investigated that the exact order of deposition of the various simple and complex salts of sodium potassium, magnesium and calcium, and their conditions of stability are so well known that should a similar basin be met with elsewhere, the prospecting of it could be carried out in the most scientific and least expensive fashion. Although the conditions favourable to the concentration of these minerals in commercial quantities are known to exist in several localities at the present day, *e.g.*, in the Dead Sea, the Caspian Sea, etc., and although similar conditions must have frequently prevailed in past geological ages, the chances of finding other workable deposits of this kind appear every year to be more remote, the ready solubility in water of the valuable minerals rendering them too liable to be dispersed again in succeeding ages and returned to the ocean, or by interaction with kaolin and halloysite converted into insoluble and valueless mica. Certain it is that in Australia no discovery of such beds was made, and supplies of potash to meet this and other emergencies had to be sought elsewhere. This search was eminently successful.

At that time only two other minerals were receiving serious attention as possible sources of potash, viz., felspar and alunite. Potassium is estimated to form 2·46 per cent.* of the whole lithosphere, and the average potassium in the earth's crust within the Australian Continent is beyond doubt very close to the average for the whole earth, so that a surface slice of Australia 10 feet deep contains about $1\frac{1}{2}$ billion tons of potassium or, on the average, half-a-million tons to the square mile. It seems almost incredible at first sight therefore that we should ever be faced in Australia with a potash famine. The difficulties of course are that this potash is irregularly distributed and even where plentiful is almost wholly present as felspar or mica and thus not readily available as plant food either in its widely distributed form or in its known concentrations. It should be borne in mind, however, that the Darling Ranges within a few miles of Perth are composed of granite with an average content of five per cent. of potash, *i.e.*, two cwt. of potash in every cubic yard, or one million tons of potash per square mile 10 feet thick. Not only is there this huge amount of

* F. W. Clarke, data of Geochemistry, 4th edition (1920).

five per cent. potash ore at our very doors, but in the same ranges are numerous concentrations in the shape of pegmatite veins in which the potash is estimated to rise to 7 or 8 per cent., and these by hand picking would yield raw material with at least 10 per cent. potash. It would be a worthy and profitable research to work out in the most complete detail all the chemical properties of this felspar (microcline) which in its natural state contains no less than 12 to 13 per cent. of potash,* with a view of making its potash available industrially. In some parts of the world this has been done on a small scale in connection with the cement industry by acting on the felspar and associated mica at a high temperature with lime and a little salt and thus volatilising the potash and collecting it as flue dust. As a bye-product in cement making, however, the output is limited by the output of cement, being something like two per cent. only of the latter, an amount entirely inadequate to supply the demand. The same remarks also apply to the English attempts at recovering potash from iron blast furnaces. Other methods of utilisation have therefore to be sought.

At the local pre-war rate for potash every ton of Darling Range granite contained 32/6 worth of this indispensable material, a value almost doubled at the present time, and likely to be enhanced for many years to come. At present rates the average pegmatite veins carry 77/- to 88/- worth of potash per ton, and felspar concentrates could readily be obtained from them by hand picking which would carry £5 worth per ton. It seems as if the value of the contents is not so low as to put out of count the possibility of making the treatment of such material a commercial success, and there is every possibility of a big reward awaiting the scientist who successfully solves the problem of extracting commercial salts from such felspathic ore. Metallurgists in the past have succeeded in over coming obstacles just as great and even greater.

The principal other mineral which had been considered as a source of potash was one of a very different type and origin, viz., alunite, a basic sulphate of aluminium and potassium. Up till 1917 this mineral had only been utilised for the production of alum and very few workable deposits of it were known in the world, one of them being in New South Wales, but none at all in Western Australia. The origin of the mineral was obscure and therefore there was no scientific basis upon which to prospect for supplies of the mineral.

One of the first steps towards solving the problem of potash supplies was plainly to determine the mode of origin of alunite. A close study of all the known occurrences of the mineral led to the conclusion that it owed its origin to the oxidation of pyrites in the presence of potash mica or felspar. Plainly, therefore, alunite was

* By analysis of local felspars. See E.S.S. Sources of industrial potash in Western Australia. G.S.W.A., Bull. 77. Perth, 1919.

to be sought in areas of pyritous shales or in metalliferous districts, particularly in those parts of them where pyrites was largely developed. Following this argument, and favoured by fortune, deposits of alunite were in a short time located at Kanowna, Wallangie, Northampton and Ravensthorpe. Of these localities Kanowna soon proved itself capable of yielding large commercial supplies at a reasonable cost. At about the same time alunite was found for the first time in South Australia, at Carrickalinga and Warnertown. The first part of the problem was thus solved.

There remained to be worked out methods of treatment which would yield, 1st, a water soluble but possibly impure material suitable for agricultural purposes: 2nd, a pure or almost pure salt suitable for industrial or therapeutical use. Both have been accomplished, though the task was rendered difficult by the fact that very little was known about the chemistry of alunite, and what little had been published had been proved to be faulty. The details of the investigations have been laid before you during the year. The results obtained were briefly, that (1.) a suitable water soluble fertiliser was obtained from the mineral either by roasting or by mixing the raw mineral with a suitable amount of caustic or slaked lime: (2) a salt suitable for industrial purposes was obtained by roasting and extracting with hot water, and then crystallising.

The iron compound homologous to alunite is jarosite, a mineral considered up till quite recently to be of rare occurrence, and nowhere previously known to occur in sufficient quantities to be of commercial importance. The only known Australian locality was Coglin, in South Australia. It was obvious, however, that if a sufficiently large deposit of the mineral could be located, and if its chemical properties should resemble those of alunite, a second source of industrial potash would be available. Diligent search has led to the detection of this mineral in Western Australia at Nullagine, Whim Creek, Northampton, Love's Find, Upper Kalgan River and Ravensthorpe. At several of these localities, particularly the last, there appear to be commercial quantities. Quite recently following the publicity given to jarosite in this State, large deposits of the mineral have been shown to occur near Anglesea in Victoria.

Nothing was previously known of the chemistry of jarosite but researches now well advanced have proved that (1) a suitable water soluble fertiliser is obtainable by roasting the mineral, or by mixing it with a suitable proportion of lime, or by extracting it with lime water: (2) a salt suitable for industrial purposes is obtainable by roasting, extracting with hot water and crystallising.

The work already done on alunite and jarosite make it certain that in any serious emergency Australia can supply itself with potash.

Another potassium mineral which has received consideration is Glauconite, a hydrous silicate of potash and iron. Originally formed by precipitation in the beds of oceans, it is brought within reach of mankind by the secular upheaval of these beds into dry land. This mineral suggests itself as a possible source of commercial potash by its wide distribution in large quantities in the so-called "greensands" of many parts of the world, including our own State. In the Cretaceous rocks extending from Gingin northwards are considerable thicknesses of unconsolidated greensand consisting of a mixture of loose granules of quartz and glauconite. The latter mineral averages between seven and eight per cent. of potash and three facts make it attractive as a source of potash: Firstly, the loose nature of the mixture, which points to a mechanical concentration being cheaply and easily feasible: Secondly, the complete chemical inertness of the principal gangue, quartz: Thirdly, the chemical instability of the glauconite itself, which leaves it open to attack by many comparatively weak chemical agents. Here is a field for research distinctly inviting to West Australian chemists.

Beyond these two minerals the only other common mineral which suggests itself as a source of potash is Muscovite, the potash mica. Here again we have a mineral carrying from seven to 10 per cent. of potash but very stable and inactive, and presenting most, if not all of the difficulties of treatment of Felspar, whilst at the same time less frequently concentrated than the latter. It is quite possible, however, that the extraction of potash from mica may be simpler than from felspar, and if it should prove to be so, considerable quantities of mineral would be available for treatment, particularly if it could be treated in conjunction with felspar.

To complete the survey of the possible sources of potash in the lithosphere it was necessary to consider quite another problem altogether. This is the atmospheric weathering of rocks and the connection between this process and the nature and quantity of the dissolved salts in underground waters and, ultimately, in the waters of the ocean. I have already drawn your attention to the fact that the Darling Range granite carries in its unweathered state one million tons of potash in every square mile 10 feet deep. In addition, it carries about three-fifths million tons of soda. Now if one pays a visit to any clay or gravel pit in these ranges one finds that the granite is completely weathered over large areas to a depth of at least 10 feet, often much deeper, and that the residual material carries only traces of alkalis. A study of the processes of weathering leads one to the conclusions (1) that all these alkalis have been dissolved in surface and subsurface waters: (2) that they have not been reprecipitated in the immediate vicinity. What has become of all this dissolved potash and soda? The soda I think can be quite satisfactorily accounted for by the soda of the ocean,

river, and underground waters, but not so the potash. In the average of all these waters the ratio of potash to soda is only something like 1 to 30, whilst in the lithosphere as a whole, the soda only exceeds the potash in the proportion of 11 to 10. A prolonged and careful investigation of this problem has led to the conclusion that the greater part of the naturally dissolved potash slowly recombines with the kaolin and halloysite of sedimentary beds forming sericite. In the newer shales there is but little sericite and chlorite and much kaolin and halloysite ; in the older ones more sericite and chlorite and correspondingly less kaolin and halloysite ; in the oldest ones there is neither kaolin nor halloysite, their place being taken by sericite, and to a less extent by chlorite. It appears from this investigation that the essential difference between shale and slate is not one of physical structure but the far more fundamental one of chemical and mineral composition. A slate is in fact to be defined as a shale altered by the complete or almost complete conversion of original kaolin and halloysite into sericite and chlorite. The practical application of these results to the problem of potash supply lies in the knowledge obtained that the greater part of the potash dissolved during rock weathering is permanently lost to mankind, as it would be hopeless to attempt to extract it from slates. The balance of this potash is to be sought in deposits of glauconite, alunite, jarosite, and a few lesser known minerals, many of which are undoubtedly more abundant than has hitherto been supposed.

The discussion of the utilisation of other sources of potash than those of the German mineral salts upon which we have become so dependent, raises the general question of what may be called the metallurgical interest of the chemist in Nature's chemicals, that is to say, the interest which should be taken in the study of the chemistry of the minerals of the earth's crust with a view to converting them more readily and more economically into the commercial products necessary for our every day life. One might be tempted to say at first sight that the cyanide process has led to such a convenient and cheap means of extracting gold from its ores, that here at least there is no room for experimentation. Yet we know that gold millers raise increasing complaints regarding the cost of treatment, and so long as cyanide remains a comparatively high priced chemical, and so long as no solution to the problem of preventing the large destruction of cyanide by such common associates of gold as arsenopyrite, iron sulphates and copper carbonates, there is ample room for the mineral chemist to work a revolution in the wet extraction of gold.

At a later stage I shall refer somewhat more fully to the sources of our natural supplies of phosphorus. The metallurgical aspect appeals to us in the case of this substance. A somewhat recent paper* on the phosphates of Florida read before the American

*J. A. Baw: "Use of Low Grade Phosphates."

Institute of Mining Engineers, makes the astounding acknowledgment that only 25 per cent. of the phosphorus in the crude rock which is worked is actually recovered, 75 per cent. being lost in the tailings. Here is food for thought for anyone interested in problems of economy of natural resources. In our own case, so long as we have a plentiful supply of high-grade phosphate rock coming to us from over the seas we remain in the same calm state of contentment as we did in regard to our potash supplies, and make little or no effort to utilise local lower grade or less soluble minerals. It is quite possible, however, that through some cause or another our overseas supplies may one day be stopped or at least reduced to less than our reasonable requirements, and it would not be out of place therefore for our scientists to interest themselves in our Australian phosphatic minerals and make a complete study of the chemistry of these substances with a view to their economic utilisation.

Other similar cases will suggest themselves on a little mature consideration. For example, how was it that although before the war the British Empire produced about three-quarters of the tungsten ores of the world, and utilised more than one-half of the pure tungsten compounds prepared from them, the metallurgy of the metal was left wholly in the hands of the Germans, with very serious results from a munition point of view in the early days of the war.

It is astonishing to note to what an extent in the past the chemical side of the science of Mineralogy has been absolutely neglected and the physical side, particularly the crystallographic and optical, developed to extremes. As a matter of fact the utilisation of minerals in the service of mankind depends, in nine cases out of ten, on their chemical properties and not on their physical. Just consider for a moment how few minerals are used like diamonds or quartz for their optical properties, or asbestos for its infusibility, or mica for its resistance to the passage of the electric current. And on the contrary, how very many economic minerals depend entirely for their value upon their chemical properties, for example, pyrite, or apatite, or calcite, or salt. There is undoubtedly a crying need for a much fuller treatment of the chemical properties of minerals in our text books and courses of study. Who can doubt which is the more important piece of knowledge to impart to a student of mineralogy, that haematite crystallises in the hexagonal system, or that haematite is reduced to metallic iron when heated to a high temperature with carbon.

A new branch of geochemistry which promises to yield many results of great practical importance has recently been brought into prominence through the researches and publications of a Russian professor of Mineralogy, J. V. Samoilow of Moscow. This science though essentially chemical and mineralogical in its scope,

has been given by Samoilow, the most misleading name of Paleophysiology, a name which I trust will soon pass out of use in favour of one more truly significant. The science deals with the origin and development of those minerals in whose history animal or vegetable organisms have played an important part as primary or later concentrating agents. Its practical application is likely to lie in the assistance it will render in the search for new deposits of certain economic minerals, such for example as apatite and celestite (strontium sulphate), and in the economical exploitation of such deposits, since it will soon be possible in the light of the new facts of this science for the prospector and miner in such instances to profit to a very considerably greater degree than heretofore from the historical, palaeontological and structural data collected by the field geologist.

The foundations of this branch of science were laid many years ago, when the relationship was first established between economically important beds of limestone and the powers possessed by corals, echinoids and other marine organisms of extracting from sea water and secreting again in their skeletal systems the carbonate of lime present in such a diluted form in the waters of the ocean. But for the primary concentrating power of such organisms our supplies of lime compounds of all kinds would be infinitely more difficult to obtain than they are at present. With the present abundance of calcite of sufficient purity for most of our demands there is, however, no urgent call for the scientific investigation of the many organic sources of calcite and aragonite and of the history of their development into commercial deposits.

Another section of this science to which in the past a good deal of attention has been paid is the origin and history of our available phosphate deposits. Here we are, however, immediately on a different footing to what we were in the case of calcite, whether from a standpoint of scientific interest, of economic importance, of complexity and multiplicity of the chemical changes involved and final products resulting, or of discontinuity in the data available. No exposition of the facts of this series of chemical reactions approaching anything like completeness has ever been published, nor will be for many years to come. Yet consider one small practical application of such a complete mass of data accompanied by reasoned deductions and generalisations. In Western Australia we are in constant need of a cheap supply of phosphates suitable for agricultural purposes. To the north of Perth is an immense area of rocks which at several points exhibit outcrops of natural phosphates either slightly too poor or too insoluble to use under present conditions. The stratigraphy of the region is not obscure, but without the necessary knowledge of the past methods of formation and accumulation of the phosphate minerals, we are at an absolute loss where to look within this region for higher grade and

more soluble crude material. in fact we are not in a position to decide whether there is any hope at all of finding such more valuable ore.

A brief resumé of the accepted theory of phosphorus concentration may serve to draw attention to the many weak points in our chain of knowledge which requires further investigation. The origin of all the phosphorus now available to man is the phosphorus of the primeval surface magma, which has crystallised out in the present lithosphere almost entirely as apatite, the fluophosphate of calcium. The average phosphorus content of the lithosphere is 0·28 per cent. of P_2O_5. A large decrease in concentration takes place when this apatite passes into solution in the soil waters, and thence into vegetable organisms. From the latter a small proportion of the total phosphorus passes into land animals where large concentration occurs, placing within reach of man for his use an appreciable tonnage of "bone phosphate." By far the greater part of the phosphate dissolved from weathoring rock passes however into the ocean in an extreme state of dilution, where it is first absorbed by marine flora, subsequently by the intervention of fish, arthropods and mollusca, and in past ages by marine reptiles, reaching an appreciable concentration in the bony framework of such creatures. Fish bones as such, are not used to any great extent as a phosphatic manure, but the ingestion of bony fish by other carnivorous fish as well as by reptiles and birds, all of which excrete the greater part of the phosphatic material in a new and more soluble form, has led to the chief concentration upon which man depends for his supplies of agricultural phosphorus. The guano deposits and associated rock phosphates are fairly well known, though the total number and chemical nature of tho various minerals occurring in them is not yet known with any certainty. The story of the fish and other phosphatic excreta which passes directly into the water of the ocean, and how this came to be collected together into beds of coprolite and of phosphatised wood, both important fertilisers in Europe and America, and likely to be in Western Australia, is at present a closed book.

There is plainly room for a large amount of scientific work in the story of the cycle of natural phosphorus, including investigations of the actual organisms which are capable of secreting phosphatic materials, and the form and proportions in which it is secreted, the concentration and chemical composition of the phosphorus compounds formed at all intermediate stages, and their solubility in natural waters, and finally, the composition and chemical properties of the many minerals occurring in the natural concentrations now used or still lying useless through insufficient concentration or deficient solubility.

Prof. Samoilow has devoted some time to this phosphorus question, but complains with others of the almost total absence

of precise chemical analyses of the skeletal parts of living organisms. One of the most striking results of Samoilow's development of this new science was greatly helped by the discovery of F. E. Schulze, that portions of the skeletal system of the Xenophyophora, a group of marine Rhizopods, consisted of almost pure barium sulphate in the form of minute granules. According to Samoilow the abundance of living organisms of this type off the coast of Ceylon amply explains the abundance of nodules of barite which can be dredged from the sea bottom in the locality, and points to the possibility of an abundance of such organisms in the past being the explanation of the occurrence of similar nodules of commercial importance found in certain marine beds in Europe. On the strength of this generalisation he has been able to trace numerous important occurrences of barite in Russia to a very limited geological horizon, to prove their wide extension within, but not above or below this horizon, and to predict their extension to regions not hitherto recognised as carrying concentrations of barium sulphate. This is a fact of far reaching importance in its influence on the work of the economic mineralogist.

Following on this discovery Samoilow turned his attention to one of the chief sources of commercial strontium, viz., the celestite (strontium sulphate) deposits of Turkestan. Here again the whole of the deposits appeared to be confined to sedimentary rocks of a limited horizon and the discovery by O. Bütschli that strontium sulphate was a major component of the skeletal substance of the Acantharia, a group of Radiolaria, led to the conclusion by Samoilow that these celestite deposits owed their origin to similar causes to those which produced the Russian barite deposits, viz., the extraction from sea water, and concentration of the minute proportion of strontium there existing, by the agency of living organisms. This conclusion must necessarily affect profoundly all future prospecting and exploitation of this mineral in sedimentary formations.

Samoilow has further pointed out the fact that other valuable metals, viz., copper, vanadium and manganese are essential and concentrated constituents of portions of certain living animal organisms and may have been to a much greater extent in past ages. He has discussed the extent to which this fact may influence our present theories regarding the origin and distribution of those necessary metals in the following words:—

> * "The deficiency of our knowledge with regard to the chemical composition of contemporaneous animals is very much hindering the progress of the investigation of this problem. . . . . . It would scarcely be reasonable to suppose that all the facts concerning this problem are restricted to those so recently and so unexpectedly dis-

* Minl. Mag., 1917, xviii., pp. 97-98.

> covered, and that we are standing before some new and not less remarkable discovery. But even remaining within the limits of the facts already established, we must concede that a thorough mineralogical elucidation of the nature of this accumulation of strontium, copper and vanadium through the agency of vital processes should be considered seriously. And when we admit that the various organisms characterised by these mineral properties, although less numerous in the contemporaneous epoch, might have been more abundant and appear as a common and widespread group at some remote period of the earth's history, it will be clear then what importance must be attached to the detailed elucidation of all these questions for the proper understanding of the genesis of various minerals occurring in sedimentary rocks."

With this quotation from the pen of a distinguished foreign scientist I will bring my address to a close. I have endeavoured to-night to direct your attention to the moribund state of one of our greatest industries, and to the necessity for its rejuvenescence on broad grounds of national insurance. In doing this I have sketched for you one or two successful scientific investigations which have led to the utilisation of new minerals or the discovery of new sources of long known ones, and I have suggested directions in which scientific research may be expected to benefit the mineral industry and at the same time increase the security of the Commonwealth. Now more than ever is our country ready to benefit from the work of our scientists, and I feel sure that they will rise to the occasion.

EDWARD S. SIMPSON.

NOTES ON WESTERN AUSTRALIAN PETRELS AND ALBATROSSES.

By L. Glauert, of the W.A. Museum.

(*Read on 10th August*, 1920.*)

These notes on species of Turbinares obtained on the coast of Western Australia during the winter of 1920, include the first authentic record of the presence of the Cape Petrel (*Petrella capensis*) in Australia, and extend the known range of several other species. The specimens referred to are now in the collection of the Western Australian Museum, Perth.

The nomenclature is that of the R.A.O.U. Check List of 1913 with alterations adopted by the Check List Committee.

Pterodroma mollis Gld.—Soft plumaged Petrel or Shearwater. —On May 29th, I found an injured specimen of this rare bird some distance from the beach at Cottesloe. Its wing was broken when found and the bird died about half an hour later.

When dissected the stomach was found to contain cephalopod beaks and the remains of a cephalopod eye.

A specimen of this bird was picked up dead on the beach at Cottesloe on August 8th, 1919, by the late Mr. F. L. Stronach, as a result of which the bird was restored to the Australian list from which it was removed by Mr. Gregory Mathews in 1913.

The only known examples are in the Western Australian Museum.

The type locality is the Southern Atlantic Ocean.

Macronectes giganteus (Gmelin)—Giant Petrel.—Several specimens of this bird were received at the Museum during 1920. It appears to have been rather abundant.

The type locality is Staten Island, Tierra del Fuego.

Petrella capensis (Linné)—Cape Petrel or Cape Pigeon.—On June 23rd, Mr. F. L. Stronach presented a fine specimen of this bird which he had found on the beach some little distance north of Cottesloe. When examined it proved to be an immature male.

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* By permission of the Trustees of the Museum.

On October 26th, Mr. Stronach donated a second specimen, also found to the north of Cottesloe. The specimen was mummified and had evidently been dead for some considerable time. In spite of its poor condition it has been added to the reserve collection on account of its rarity. The sex of this bird could not be determined.

This species has often been seen off the Australian coast, but prior to Mr. Stronach's first discovery had never been actually captured in Australia.

The type locality of the species is the Cape of Good Hope.

Pachyptila vittata (Gmelin)—Broad Billed Prion or Dove Petrel.—This bird does not seem to have been at all plentiful in 1920. No specimens arrived at the Museum and I saw very few on the beach. The first specimen to reach the Museum was one I collected north of Osborne on July 3rd, 1917, at which time only one specimen, then in the collection of Mr. Gregory Mathews, and now in the British Museum, was known.

Pachyptila desolata (Gmelin)—Prion or Dove Petrel. — As usual large numbers of Prions were lying dead on the beach. They can be distinguished from the preceding by the shape of the bill and smaller size.

Diomedea (*Thalassarche*) *melanophrys* Temm.—Black-browed Albatross.—This albatross, which is exceedingly common off the south coast of Australia, is rarely met with along the west coast, the extreme limit being Cape Naturaliste (Ferguson).

By the taking of a specimen at Cottesloe on August 21st its range is considerably extended.

The type locality of the species is the Cape of Good Hope.

Diomedea (*Thalassogeron*) *chrysostoma* Forster.—Grey-headed Albatross.—A specimen of this Albatross or Mollyhawk was a welcome addition to the collection, though not of particular interest, as a living bird had been captured by Mr. Stronach at Cottesloe in 1917.

Diomedea (*Thalassarche*) *chlororhynchus* Gmelin — Yellow-nosed Albatross—Two decomposed specimens were seen on the beach south of Cottesloe on August 21st.

THE TERRACES OF THE SWAN AND HELENA RIVERS AND THEIR BEARING ON RECENT DISPLACEMENT OF THE STRAND LINE.

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and

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(*Read 10th August*, 1920.)

CONTENTS.

Physiography.—Evidence of uplift has been produced from a number of widely separated places on the Australian coast. The Western Australian evidence has been summarised by Jutson (10), who, however, saw no direct indications of uplift in the Swan River District, though he had stated (9) that uplifts may have taken place. Woodward believed that uplift was in progress at Fre-

mantle (3), but did not produce adequate evidence to support his belief. Somerville has recently placed the matter beyond doubt (16), by recording and describing numerous features in the Perth District which are indisputable evidence of a recent displacement of the strand line, resulting in an apparent uplift of 23 feet from the present high water level. We considered that this movement should have been clearly recorded by the terraces of the Swan and Helena rivers, and, therefore, investigated the problem. Since the appearance of Daly's suggestive papers (18, 19), recent uplift has assumed world-wide importance, and we have attempted to apply the results of our work as a test of Daly's hypothesis. As great uncertainty now prevails in the use of the terms "elevation and subsidence of the land," "displacement of the strand line," and "eustatic movement of the ocean," we shall use the term "rejuvenating movement" when speaking of the recent changes of the Swan and Helena rivers.

The Swan and Helena rivers, having terraces developed above the tidal limit, and raised beaches below it, are similar to the Moonee River, Vic. (6), which has terraces associated with raised beaches. We suggest that the investigation of river terraces has an important bearing on the problem of eustatic movement.

The Segments of the Swan River.—Somerville (16) has divided the lower Swan into convenient physiographic segments, each of which has fairly uniform features. To these we add two further segments. From Burswood to Guildford, the river flows through a wide valley, the sides of which are obscured by recent sand dunes. This segment is transitional in nature, for here the more evident features of the lower segments, which are due to the drowning (9, 10), prior to the rejuvenating movements, give way to features usually ascribed to uplift. From Guildford to the foothills of the Darling escarpment, beyond Upper Swan, the river flows in a valley, which Jutson terms "precociously mature," and exhibits all the characters of a river which has reached maturity after several successive rejuvenations. The Helena joins the Swan at Guildford and is similar to the Swan, from where it also emerges from the escarpment, but has a slightly steeper gradient, and is, therefore, more juvenile.

The Swan Coastal Plain.—This prominent feature of the physiography of Western Australia has been adequately described by Jutson (10), in a broad way, while Woolnough has elaborated the description and recognises in it a series of distinct elements (15). We shall compare the features of rejuvenation existing in the Perth District with other features, further afield, which have not yet received detailed study, but may reasonably be ascribed to the same causes, especially if Daly's hypothesis be correct. The lakes marginal to the sea, between Bunbury and Mandurah, form a pro-

minent physiographic line, and their parallelism and serial arrangement call for an explanation which we believe is given by the rejuvenating movements which affected the Perth District. The explanation we shall give of the Rottnest lakes confirms our opinion concerning the Bunbury lakes.

The Islands off Fremantle.—Garden Island, Carnac, and Rottnest represent a former westward extension of the coastline, and were probably separated from the present coast by local subsidence (10). They are formed of Coast Limestone (a consolidated, carbonate dune rock) and of recent sand dunes. Rottnest, which encloses a group of salt lakes, gives very clear evidence of having been affected by rejuvenating movements.

The whole island is surrounded by a reef, or wave-cut platform, which extends for half a mile or more to sea, where it ends abruptly, being undermined by the waves. The solid reef limestone appears to rest on unconsolidated sands. At high tide it is covered by three to four feet of water off-shore, whence it shallows gradually to the shoreline, where it ends usually in a beach, or on headlands and exposed places, against low, undercut cliffs of limestone. It is the product of recent wave action, with a very low wave base, owing to the shallowness of the surrounding sea. The modern beaches are often bordered to landward by a low raised beach, indicating a movement of about eight feet. An older, elevated platform replaces the raised beaches on the rocky shores and stands about four feet above high water mark. There is also indication of a platform about twenty feet above high water mark, but owing to the rapid weathering of the coast limestones under wind and rain, and to the encroachment of recent dunes, this high-level platform is very obscure. Where recognisable, it often carries fragments of large shells upon its surface. One such platform exists at the northern end of Thompson Bay, and another extends from Nancy Cove to the Eastern end of Strickland Bay. The platforms are interpreted as elevated reefs.

The shores of the salt lakes expose a most interesting section composed almost everywhere of consolidated shell beds, which extend to greater heights than the present shores of the lakes, and end frequently against undercut limestone cliffs, the bases of which are about eight feet above high water mark. Elsewhere the shell beds extend far inland, marking former extensions of the lakes, as at the north end of Garden Lake. In a few places, the beds mark old shorelines at a greater height than eight feet, as at Padbury's Flat. The shells are very abundant, and are well preserved, the two valves of pelecypods often being united. The shells belong to existing species, and form a very different assemblage from that of the shell beds of Perth and Melville Waters. Associated with the Rottnest shells are one echinoid, one serpulid worm, and one

large foram. These beds show that the lakes were formerly less saline, and were connected with the sea. Their elevation above the present strand suggests that the closing of the lakes, and the union of two or perhaps three islands to form the present Rottnest, were effected by the rejuvenating movements. It also affords an explanation of the salinity of the lakes. The coast limestones are exceedingly porous, and the great loss of water from the lakes by evaporation during the hot and dry summer can only be counterbalanced by percolation of sea water through the limestone, which in turn implies continuous increase in salinity. The fresh water gained by the lakes during the wet winter is not competent, in our opinion, to maintain a balance with the sea. Two points of former union of the lakes with the sea are probable, one being at the eastern end of Government House Lake, leading into Thompson Bay, the other being at the site of the proposed canal at the northern end of Lake Bagdad. The drifting of sand bars and dunes and the rejuvenating movements combined, we believe, in closing the lakes, and evaporation balanced by percolation from the sea has rendered them saline. Both actions have caused the extinction of the shell fauna.

GEOLOGY.

The Crystalline Plateau.—The terraced segment of the Swan River is flanked on the east by the fault scarp of the Darling peneplain. The scarp has been described by Jutson (10), and the features of the uplifted peneplain by Woolnough (13). In the Guildford District, the plateau escarpment is composed of a variety of granites, which do not appear to show any clear marginal relationship to each other, one type grading imperceptibly into the next. They are believed to be Pre-Cambrian in age, and are penetrated everywhere by a plexus of basic dykes, here for the most part epidiorites, though dolerites are also known to occur. Further north, beyond Upper Swan, a gneissic series makes its appearance (9), but it has received little investigation.

The Guildford Clays.—The Swan itself flows over the Guildford Clays from Upper Swan to Guildford. This formation extends right up to the foot of the Darling escarpment, and is claimed by Woolnough as part of a continuous piedmont apron (15). This view seems to be fully justified, but the relationship of the Guildford clays are not entirely apparent. They have claimed attention since 1884, owing to their artesian water content. With their associated beds they form a distinct series, which we shall term the Guildford beds. They extend to a great depth, as is shown by the bore sections (8), and are of irregular character, without persistent horizons. They contain beds of hard sandstone in some places, but, as a rule, are not well consolidated. In lithological character they vary from red clays to sandy clays, gravels, sandstones, and

even to calcareous sands. In the railway cutting, on the north side of the Swan, at Upper Swan, they show signs of contemporaneous erosion. Lithologically they have been thoroughly described by Hardman and Nicolay (1, 2). Simpson refers to them as being of Mesozoic age (7). They afford no palaeontological evidence. Shells are found in the bore sections of the Perth District, but are absent from the Guildford bores (5). They are best considered as a piedmont deposit, post-dating the formation of the Darling escarpment.

Drift Sands.—The Western bank of the Swan, between Guildford and Upper Swan, is bordered at a varying distance by dunes which have been fixed by vegetation. The dunes belong to the coastal dune belt, but are here siliceous rather than calcareous. They represent the earlier accumulations during the period of coastal progradation, which preceded the cycle of drowning referred to previously (10). All the rivers of the Swan Coastal Plain appear to be consequent upon the Darling escarpment, but the encroachment of the dunes has had a powerful effect in deflecting the streams on the plain (10), and the Swan has been forced, in the Guildford District, to take a subsequent course over the Guildford beds, until, by gathering strength from the Helena and the Canning, it has attained supremacy over the dunes. The surface of the Guildford beds slopes gently to the south, but the western gradient, on the western side of the Swan, is sufficient to cause stagnation of the drainage from the high dunes, with the result that a number of swamps have formed between the dunes and the river.

The Terraces and Levels.—In order to investigate the terraces four lines of levels were determined by theodolite, crossing the valleys of the Swan and Helena (the latter in two cases only), approximately at right angles. From the levels obtained, profiles were plotted on a uniform scale, and these, combined with an examination of the ground, have led us to our conclusions. Four physiographic levels have been clearly revealed, and a fifth is believed to exist, but is not so well marked nor so well preserved as the remainder. The uppermost level is that of the surface of the Guildford beds, the lower levels being indicated by river terraces. As the terraces are developed symmetrically in both rivers, and correspond very closely, they are of the type usually ascribed to uplift (11).

The uppermost, or *Caversham level,* is the original erosion surface of the district. It has an elevation of 44 feet above survey datum at Guildford and Midland Junction, and slopes very evenly upwards to the north, being 70 feet above survey datum at Upper Swan. In this level the Swan and Helena eroded their original paths over the Guildford beds, and developed broad and precociously mature valleys until the close of the cycle of drowning. The thalweg so formed constituted the *Guildford level,* which is now

represented by a well marked terrace in both valleys. It is very well developed at the Old Golf Links on the northern side of the Swan at Guildford. The Guildford level is traceable almost continuously for a long distance up both valleys. At Guildford it is 13 feet below the Caversham level in the valley of the Swan, and seven feet below it in the valley of the Helena—a nice expression of the relative powers of the two rivers. At Albion Town north of Herne Hill it is nine feet below the Caversham level, and at Upper Swan it is very feebly developed. It is here represented by obscure shoulders on the Caversham slopes, and we estimated its depth by diagrammatic means to be only five feet below the Caversham level. It is, however, quite traceable in the landscape. The Guildford level therefore rises towards the Caversham level proceeding upstream. This is what would be expected during a period of stillstand, or of slow subsidence (4). Rejuvenating movement now supervened, and the soft Guildford beds became entrenched below the Guildford level, leaving it as a river terrace. This first phase of the rejuvenation is marked by distinct remnants of a once continuous terrace in both valleys, but the new thalweg which it represents as having developed below the Guildford level has been greatly obscured by the subsequent development of the rivers. This third level is clearly shown to the south of West Midland railway station, in the valley of the Helena, and we have named it the *West Midland Level*. At Guildford the West Midland level is eight feet below the Guildford level in the Swan Valley, and 10 feet below it in the Helena. Again we have a response to steeper grade in the Helena. At Albion Town this level is 30 feet below the Guildford level, and at Upper Swan is 31 feet below it. The level is easily traceable in the scenery, and we are not in doubt about its identification. We are here dealing with the effect of the steady and continuous increase in the corrasive power of the Swan under the influence of rejuvenation, and as this power increases by "compound interest" in proceeding up a normal stream from its mouth, the relative increase in corrasive power under rejuvenating influences is very much greater than in the normal condition. The rule may be restated that *levels due to rejuvenation will diverge from the older levels of stillstand or subsidence in proceeding upstream.* (c.f. 4.) In other words, the further we go towards the head of the Swan, the greater will be the vertical interval between the Guildford and the West Midland levels (terraces).

The West Midland level only marks a pause in the process of rejuvenation. When the movement started again further entrenchment took place, the second pause being recorded clearly in the Helena but less distinctly in the Swan valley. At Guildford, seven feet below the West Midland terrace, in the Helena valley, is another terrace which we believe records a fourth level. At the Old Golf Links at Guildford, in the Swan valley, is a lower platform which

corresponds to this level, and at Albion Town there is a terrace greatly dissected by ox-bows, standing five feet below the West Midland level. Other features to be considered render it extremely probable that a true level exists in this position, and that we are not dealing with accidental terraces. We have named the fourth level the *Helena Level*. When the width of the present valleys is considered, the presence of clear and continuous records of the Helena and West Midland levels is seen to be impossible. The Swan now meanders in a valley as wide as that of the Guildford days.

The lowest level is that of *the present flood plains*. At Guildford the present flood plain of the Swan is 15 feet below the West Midland level. At Albion Town the distance has not increased, but at Upper Swan it rises to 18 feet. The depth of the Helena flood plain below the West Midland level is 13 feet in the western profile and 11 feet in the eastern, the distance between the two being only half a mile. In both cases it is well above the flood plain of the Swan, indicating the steeper gradient of the Helena.

The significant inference from the foregoing details is that the total intervals due to rejuvenation (Guildford to present levels) in both rivers in the Guildford District are of the same order, that is, about 22 feet, as indicated by the profiles. Now, as a corollary to the previous rule, we state that *the intervals between river terraces due solely to rejuvenating movements will be equal to the actual amount of displacement only in the vicinity of base-level.* But the maximum "uplift" recorded by Somerville is 23 feet (16). We conclude, therefore, that the river record of the Guildford District is an actual measure of the rejuvenating movement, and that Guildford was near base-level. Jutson states correctly (9) that the Swan is affected by the tides as far as Guildford at the present day.

The levels should prove useful in the study of rates of erosion if Daly's hypothesis be proved ultimately to be correct, as the terraces are dissected by innumerable brooks the ages of which can be gauged accurately. Sub-surface drainage (14) was observed at Upper Swan.

Notes on the Profiles.—Profile No. 1 shows the Caversham, Guildford, West Midland, and Present levels in the Swan valley, the West Midland level being here slightly truncated. Guildford itself is on a remnant of the Caversham-Guildford slope. In the Helena Valley the Caversham, West Midland, Helena, and Present levels are shown. Profile No. 2 shows the same levels as No. 1 for the Swan, the West Midland level being again truncated. In the Helena, the Guildford, West Midland, and Present levels appear. Both of these profiles were brought into line with survey datum by tying the traverse on to a railway bench mark. Profile No. 3 (near Albion Town) shows an encroachment dune on the west, and the Caversham,

Guildford, West Midland, Helena (?), and Present levels. From Susannah Brook to the east this profile was completed by inspection of the ground, not by theodolite levelling, owing to lack of time and a failing light. The levels observed were corrected to survey datum by the height of Herne Hill siding, which is on the Caversham level (17). Profile No. 4 (at Upper Swan) shows the Caversham, Guildford (obscurely), West Midland, and Present levels, and an intermediate terrace between the Guildford and West Midland levels. The last is interpreted as a stiff-off terrace (11), a type likely to be encountered upstream where corrasive power is at its height. The West Midland level was identified with certainty by plotting the gradients of the levels to scale on squared paper, which rendered its harmony with the system apparent. As with No. 3, this profile was co-ordinated with survey datum from the height of Upper Swan Siding (17), which is also on the Caversham level. Profile No. 5 is an idealised representation of the levels as shown by both rivers. Profile No. 6 shows the gradients of the levels along the course of the Swan, and, like Nos. 3 and 4, gives a very clear idea of the divergence of the levels due to rejuvenation, and of their convergence during stillstand or subsidence in upstream sections. It was by means of this diagram that the truncation of the West Midland terrace in the Guildford District was first recognised.

The heights of the levels for the various profiles are tabulated below. The levels are numbered in descending order of age; heights are stated in feet.

	Guildford.				Albion Town.	Upper Swan.
—	Helena.		Swan.		Swan.	Swan.
	a.	b.	a.	b.		
1	44	44	44	44	62	70
2	...	37	29	29	53	65 ?
3	25	25	21 ?	21 ?	23	32
4	18	...	...	...	18	...
5	12	16	10	8	8	11

THE CYCLES OF EROSION. It will be conceded that the interval between two succeeding and persistent levels indicates a cycle of erosion. The levels here recognised correspond to four such cycles. The first, or *Guildford cycle*, represents the difference between the Caversham and Guildford levels, and was the initial cycle. It was a period of subsidence followed by stillstand (the drowning referred to by Jutson and Somerville). The interval between the Guildford and West Midland levels, or *West Midland cycle*, was a period of rejuvenation. After a pause the *Helena cycle* was initiated, we believe with further rejuvenation. After a second pause the *Present cycle* was ushered in with rejuvenation, which has now given place to stillstand. The amounts of entrenching done during these cycles

are given below for comparison with the previous table. The cycles of erosion are numbered in descending order of age. The figures represent differences in feet between succeeding levels. Queries to figures indicate a possible error of a foot, while queries alone indicate that the necessary levels are not developed in the particular profile.

	Guildford.				Albion Town.	Upper Swan.
	Helena.		Swan.		Swan.	Swan.
	a.	b.	a.	b.		
1	?	7	15	15	9	5 ?
2	?	13	8 ?	8 ?	30	33 ?
3	7	?	?	?	5	?
4 ... 1 ...	6	?	?	?	9 ?	?
2 ... 2 ...	19	19	23 ?	23 ?	39	39 ?
3 ... 3 ...	?	?	?	?	35 ?	?
4 ... 2 ...	11	?	?	?	14 ?	?
4	?	22	21 ?	21 ?	44	53

Correlation with the Features of "Uplift."—The differences in height between the levels of rejuvenation in the Guildford District (believed to have been in the vicinity of base-level throughout), and the amount of movement indicated, are tabulated below:—

Levels.	Difference in Height.	Movement.
	ft.	ft.
Guildford to West Midland...	8	8
West Midland to Helena	7	15
Helena to Present	7	22

In the *Perth District and the Lower Swan* the details of the features of uplift described by Somerville (16), if tabulated, are found to fall into three clearly marked groups, their heights above present high water level lying between the following limits:—

First Group	1ft. to 7ft.
Second Group	7ft. to 15ft.
Third Group	15ft. to 23ft.

The reader is referred to Somerville's figures and map for the details. Now, it seems evident from the above tables, that the cycles of erosion which we have defined are expressed further afield, and we correlate the third group of the features Somerville has described with the West Midland cycle. This will include the shell beds of Minim Cove and Peppermint Grove, the "raised" beach and shell beds of the Coombe, the "raised" beach of Blackwall Reach, the Crawley-Nedlands "raised" spit, and (though not described by

Somerville) the very evident higher level of the South Perth "raised" shoal, the levels of which can be clearly discerned from the junction of Labouchere Road, Lyall Street and Mends Street.

The second group corresponds to the Helena Cycle, and includes the shell beds of Hinemoa Rock, Mosman's Bay, some of the higher shell beds at Cottesloe Beach, and the "raised" spits of Points Roe and Preston, and of Peppermint Grove. The striking difference noticed by Somerville between the assemblages of shells in the beds of Mosman's Bay and Minim Cove has therefore a partial explanation if the cycles of rejuvenating movements be accepted.

The first group falls into the Present Period, and embraces the lower shell beds of Cottesloe Beach, and the associated "raised" platforms, part of Mill Point Spit, and the numerous "raised" beaches to be observed around the foreshores, at low elevations above high water mark. The last features have not been described in detail by Somerville, but are well developed, as, for instance, at Mends Street Jetty and at Applecross. These low "raised" beaches often bear a ti-tree and swamp flora.

A most important formation, if eustatic movement is to be demonstrated, exists in the hidden shell banks of Perth and Melville Waters. These beds are covered by recent sand and mud, but are frequently revealed in dredging operations, and are so rich in shells that they are used extensively for road making and reclamation. A number of different species have been collected by Dr. E. S. Simpson, and determined by Mr. C. Hedley of the Australian Museum, Sydney. Ostrea Angasi is the most abundant species. These shells are of the greatest interest, but we do not wish to anticipate Dr. Simpson or Mr. Hedley in the description of the formation, though it is necessary for our purpose to make some reference to it. None of the species is now existent in the neighbouring waters, the river indeed being almost devoid of molluscan fauna. We correlate the *Perth Shell Banks* with the Guildford Cycle, and believe them to be antecedent to the rejuvenating cycles. During the Guildford cycle the Swan broadwaters were much more extensive than they are now. The effect of rejuvenation was to restrict the volume of the broadwaters, and to render the get-away of the winter floods more difficult owing to local constrictions of the channel, especially at the Narrows. The accelerated silting, and lowering of salinity which ensued assisted in extinguishing the fauna. The shells themselves, however, indicate also an important climatic change which is a necessary postulate in Daly's hypothesis (18, 19). At *Rottnest Island* we correlate with the West Midland cycle the obscure high level platforms. To the Helena cycle are assigned the *Rottnest Shell Banks* of the salt lakes, and their associated undercut cliffs and elevated strand lines. It is possible that some of the

more elevated shell beds and shore lines belong to the preceding cycle, but this cannot be demonstrated without careful levelling. The Rottnest shell banks are as important in our local geology as are the Perth shell banks. Shells from the Rottnest banks have also been examined by Mr. Hedley, who states that they belong to existing genera, and indicate a climate similar to the present one of the locality, whereas those of the Perth banks indicate warmer conditions. The closure of the lakes, and the union of two or perhaps three islands to form the present Rottnest may be assigned to the close of the Helena cycle or to the opening of the Present period. The striking fact for the visitor is that the underent cliffs of the salt lakes belong clearly to Helena times, while those of the sea shores belong equally clearly to the present period. In the absence of careful levelling, confusion also exists concerning the "raised reefs" and "raised" beaches of the present sea shores, which belong to the borderline between the two cycles. The existing reef platforms and the underent shores of course are definitely products of very recent action.

"Uplift" has been demonstrated at widely separated places on the shores of the *Swan Coastal Plain*, but it is not our intention to deal with regional movement here. The whole question of recent "uplift" around the shores of Australia shall be reviewed by one of us (M.A.) shortly. The lakes marginal to the sea, between Bunbury and Mandurah, have been mentioned on a previous page, and shall be considered briefly. Leschenault Inlet, Lake Preston, the Martin Tank line of lakes and swamps, and Lake Clifton are long, narrow sheets of water arranged in echelon parallel to the coast. Leschenault Inlet is connected with the sea. Lake Preston is not, and is saline, and is associated with a development of the Rottnest shell banks. The Martin Tank line has an elevation of about 35 feet above sea level and is associated with a development of the Perth shell banks (*fide* Mr. A. E. Mitchell, B.Sc.). Lake Clifton, still further inland, stands about 60 feet above sea level. The sequence of events in this area seems to have been similar to that of the Swan River District, with this exception: that instead of a cycle of drowning prior to the rejuvenating movements there was here an actual uplift in pre-Guildford times, which elevated Lake Clifton. The Martin Tank line, with the associated Perth shell banks, are interpreted as the product of the Guildford cycle. Their present height above sea level is not in accordance with eustatic movement unless it be assumed that the movement of uplift was also still in progress. Lake Preston and its Rottnest shell banks we assign to the Helena cycle, and Leschenault Inlet to the Present period. We suggest that each of these lakes has been closed and rendered saline by processes similar to those which operated on the lakes of Rottnest Island.

One of us (M.A.) considers that the larger brooks issuing from the *Darling Range Escarpment* in the Swan River District show distinctly younger valley profiles in the lower parts of their courses than further upstream. As examples Jane Brook, and Narrogin Brook (Armadale), are quoted. This feature is connected with the whole period of rejuvenation. It is necessary, however, to bring to notice the factors which may assist or retard corrasion in these streams.

Corrasion may be assisted by the jointing and faulting of the crystalline plateau. Jointing is difficult to trace, but might be expected to have been recorded by a yielding formation such as the Armadale shales. The joint systems of this formation have been plotted, and are found to belong to two series, each having two sets of joints at right angles, showing in all twelve separate directions.

First series—

Set a	..	N.N.E. by N. to S.S.W. by S.
Set b	..	E.S.E. by E. to W.N.W. by W.

Second series—

Set a	..	E.N.E. by N. to W.S.W. by S.
Set b	..	N.W. by N. to S.E. by S.

The former series is the stronger, but none of these directions seem to be prominently marked in the drainage of the plateau. Faulting is more easily recognised. From an examination of the Armadale District, we conclude that the Narrogin Brook and its northern tributary follow a line of fault behind the foothill zone (15), having found a displacement of laterite level in this zone, amounting to about 200 feet, on the south side of the Canning Valley. Laterite displacement of this amount is a clear indication of recent faulting (12). A similar displacement has also been observed between Jane Brook and its northern tributary well within the Range, and the course of Jane Brook behind the foothills zone resembles that of Narrogin Brook. It is suggested that *the foothill zone is always a product of step faulting.*

Factors which may assist in the development of local maturity are of the nature of temporary base-levels. The only competent obstacles are the basic dykes. From a careful study of their outcrops we believe that *the basic dykes are more easily weathered, but less easily eroded, than the granites* of the district. The difference in both cases is very slight. Where a dyke crosses a hill at right angles to the contours it weathers out, leaving a col. Lower down the hillside the same dyke forms a ridge, for here erosion is more rapid than weathering. Similarly, where a dyke is parallel to or inclined to the contours at a low angle, the outcrop forms a distinct ledge on the hillside. So far, however, we have not seen a dyke which has become an obstacle or temporary base-level for a stream.

CORRELATION TABLE.

Cycle.	Guildford District.	Perth District.	Rottnest.	Bunbury-Mandurah.	Darling Range.
Pre-Guildford ...	Subsidence and Still-stand. Caversham Level. Dunes and Marshes	Subsidence. Dunes	Coast Limestone. (Subsidence.)	Uplift. Lake Clifton	Piedmont Plain. Mature upper parts of small streams.
Guildford. Climate warmer than at present	Guildford Level (terrace)	Perth Shell Banks.		Martin Tank line. Perth Shell Banks.	
West Midland ...	West Midland level (terrace). Rejuvenation.	Minim Cove Beds. Peppermint Grove Beds. Beach at The Coombe. Beach at Blackwall Reach. Crawley Spit. Part of S. Perth	High Level platforms.		
Helena. Climate similar to present day	Helena Level (terrace) Rejuvenation	Shell Beds at Hinemoa Rock, Mosman's Bay, Cottesloe Beach. Spits at Pts. Roe and Preston, Peppermint Grove	Rottnest Shell Banks. Raised shores and undercut cliffs of Lakes. Closing of Lakes. Raised Reefs	Lake Preston. Rottnest Shell Banks.	
Present	Flood Plains. Rejuvenation.	Shell Beds at Cottesloe Beach, Mill Pt. Raised Beaches of present shore-line	Rottnest Island. Existing reefs. Undercut cliffs of sea shore	Leschenault Inlet.	
Whole period of Rejuvenation	...	Sediments above the Perth Shell Banks	...	...	Rejuvenated lower parts of small streams.

SUMMARY AND CONCLUSIONS.

(1.) The Swan and Helena Rivers have recorded four cycles of erosion, which are marked by river terraces. The first cycle was one of stillstand in the Guildford District. The second, third, and fourth cycles were caused by rejuvenating movements, indicating an uplift of the land or a sinking of sea-level of 22 feet.

(2.) The climate of the district was warmer before the movement than it is now. This is indicated by two important formations, the older Perth Shell Banks, and the younger Rottnest Shell Banks.

(3.) The amount of movement is the same as that described as being due to "uplift" in the Perth District (23 feet).

(4.) Various physiographic features in the Perth District, at Rottnest Island, in the Bunbury-Mandurah District, and in the Darling Range east of Perth can be correlated easily with the four cycles of erosion, which may therefore be taken as the local basis for the subdivision of Recent Time.

(5.) In Pre-Guildford time actual subsidence was taking place in the Swan River District, while uplift was in progress further south in the Bunbury-Mandurah District.

(6.) The evidence of recent changes in the Swan River District supports Daly's hypothesis of a recent world-wide sinking of ocean level.

In collaborating on this paper we desire to state that the following partition of work was made. The theodolite levelling and construction of the profiles were carried out by E. A. Budge, and the general field work and correlation were done by M. Aurousseau. We also wish to thank our students Messrs. Calder and Thorburn, of the Guildford Grammar School, and Messrs. Cummins and Worboys, of the University of Western Australia, for assistance in the field work.

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EXPLANATION OF PLATES.

Plate I.	The Helena Valley, looking South from Guildford, A, on map. Shows anabranches, and terraces in the distance. E.A.B. photo.
Plate II.	The Swan Valley, looking North from Mr. Harper's house. B, on map. Shows width of present flood plain, and terraces in distance. E.A.B. photo.
Plate III. ...	The Swan Valley at Upper Swan. C, on map. Shows present flood plain, Caversham level (house on sky-line), slip-off terrace (behind haystack), and West Midland level (in front of haystack). M.A. photo.
Plate IV.	The Guildford beds and Darling Range, from Upper Swan. D, on map. M.A. photo.
Plate V.	The Rottnest Shell Banks. Between Garden Lake and Lake Herschell, Rottnest. M.A. photo.
Plate VI.	Present Marine abrasion at Rottnest. Undercut limestone West of diving pool. The man is standing on the reef. M.A. photo.
Plate VII. ...	Map of the Guildford District.
Plate VIII. ...	Profiles (to scale) of the Valleys of the Swan and Helena Rivers.

Plate I.—The Helena Valley, looking South from Guildford.

Plate II.—The Swan Valley, looking North.
(B. on Map.)

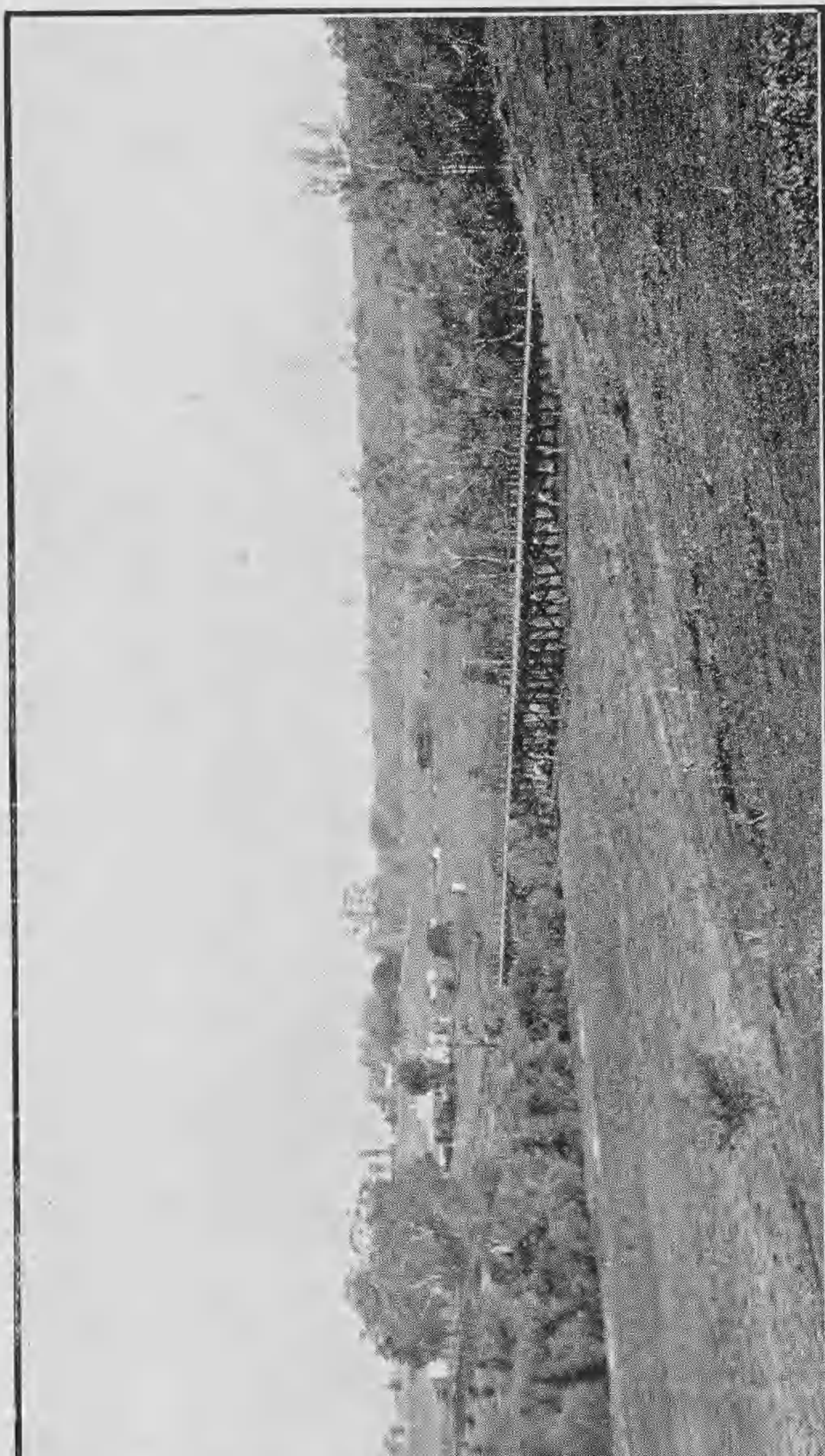


Plate III.—The Swan Valley at Upper Swan. (C. on Map.)

Plate IV.—The Guildford Beds and Darling Range from Upper Swan. (D. on Map.)

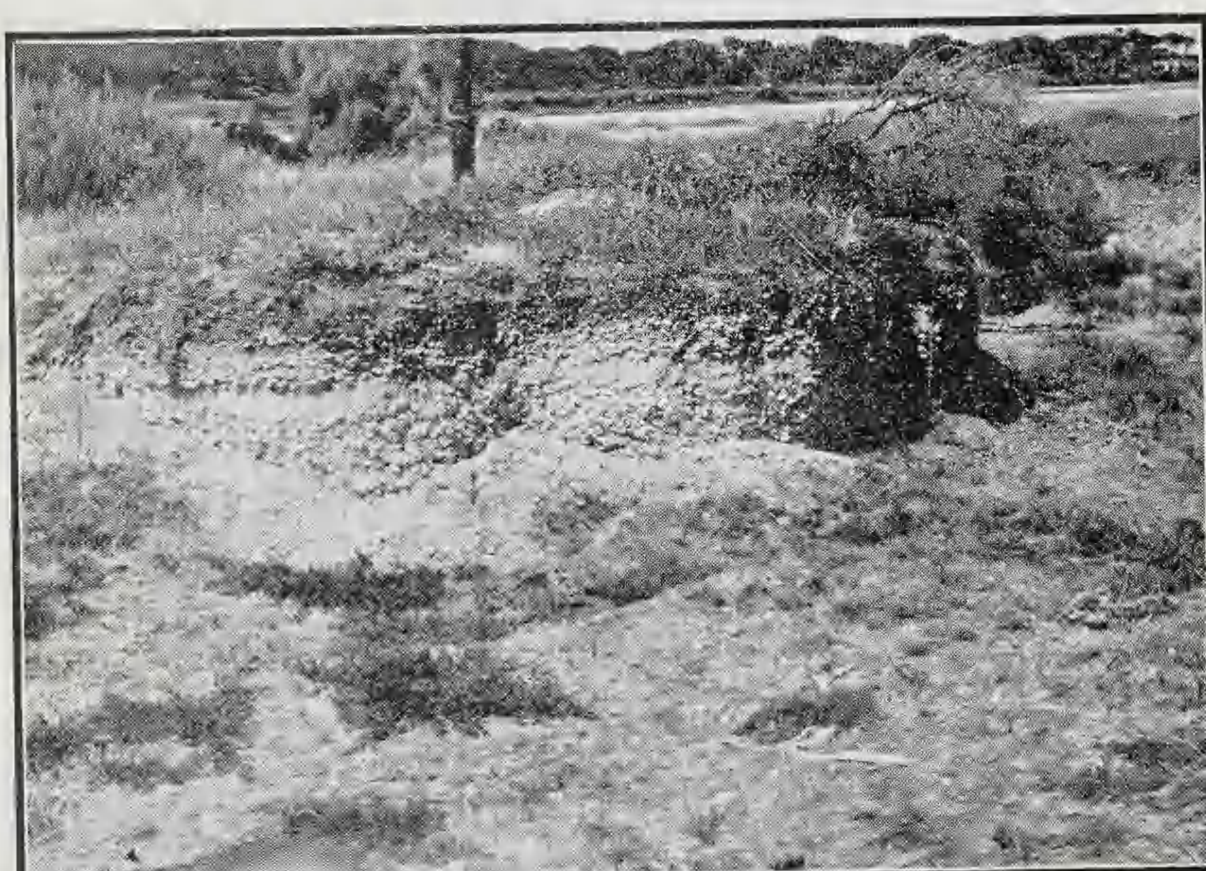
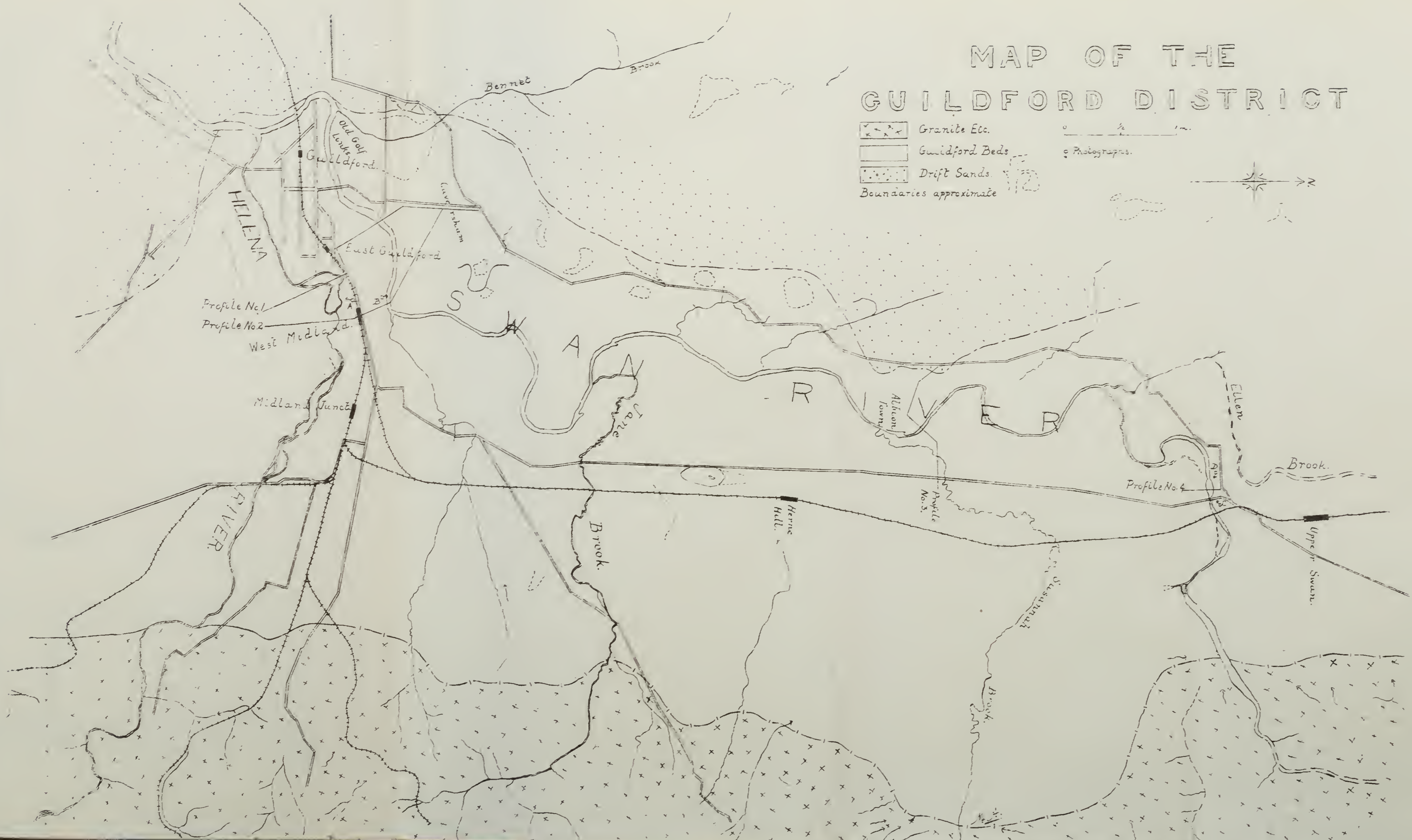
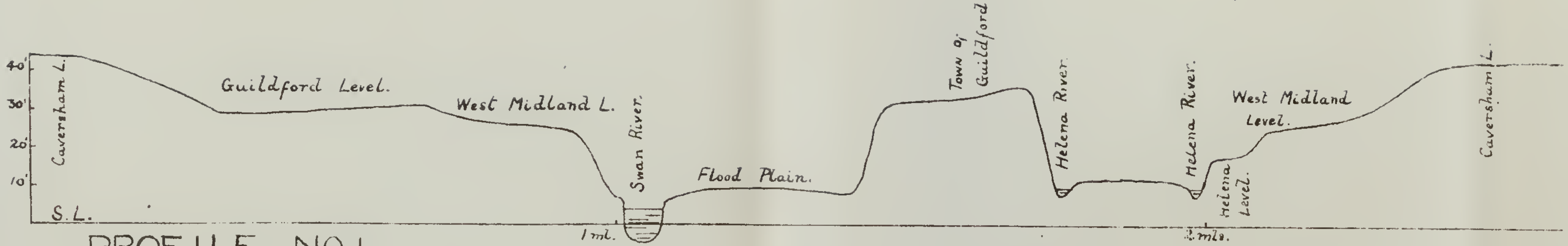


Plate V.—Rottnest Shell Banks.


MAP OF THE
GUILDFORD DISTRICT
Granite Etc.
Guildford Beds
Drift Sands
Boundaries approximate
Photographs.
Bennet
Brook
Old Golf Links
Guildford.
East Guildford
Caversham
HELENA
RIVER
SWAN
RIVER
Profile No.1
Profile No.2
West Midland.
Midland Junct.
Jane
Brook.
Herne Hill.
Albion Town
Profile No.3.
Profile No.4
Ellen
Brook.
Upper Swan.
Susannah
Brook.



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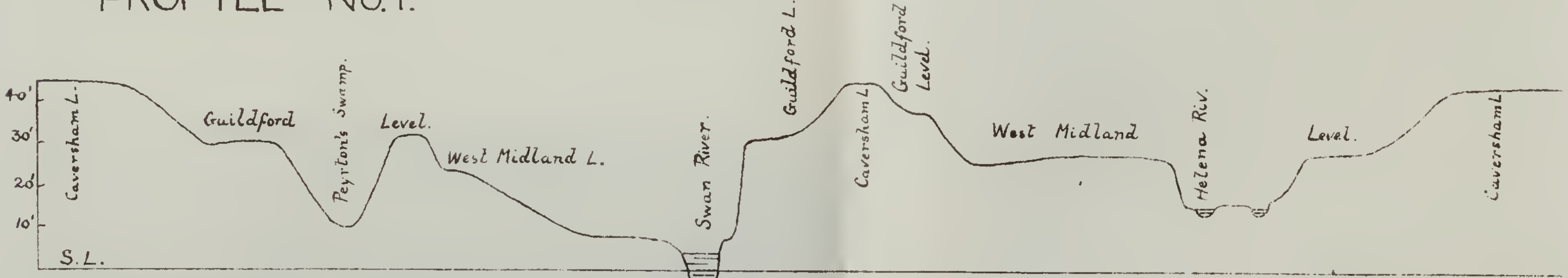

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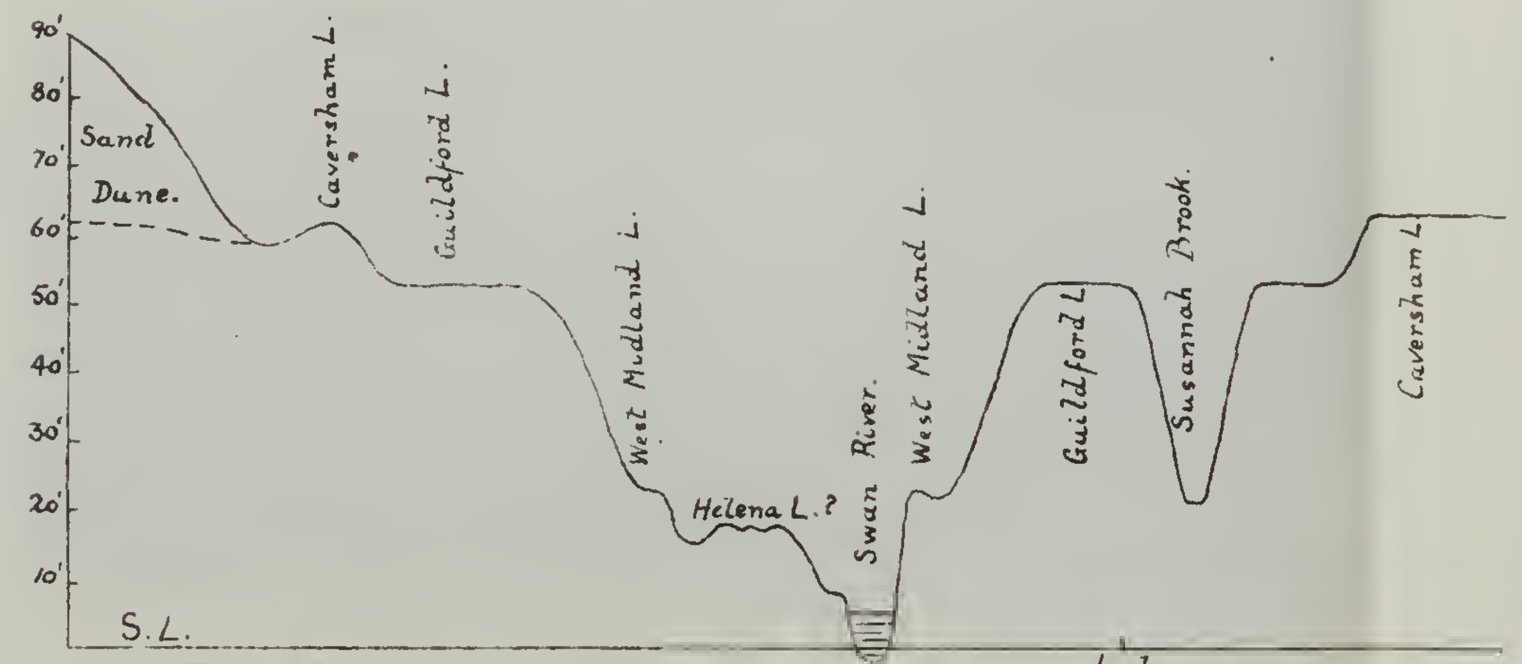

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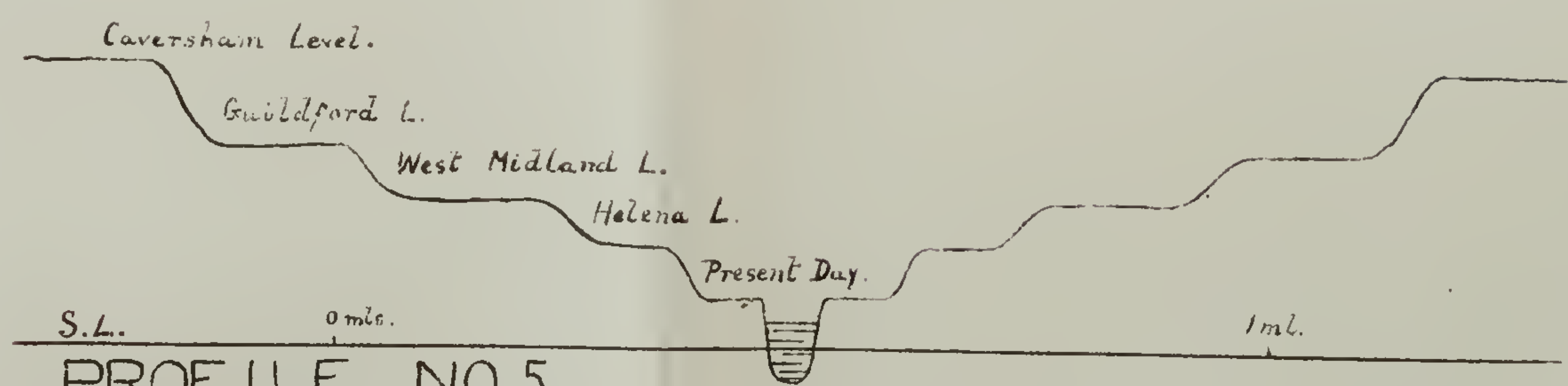

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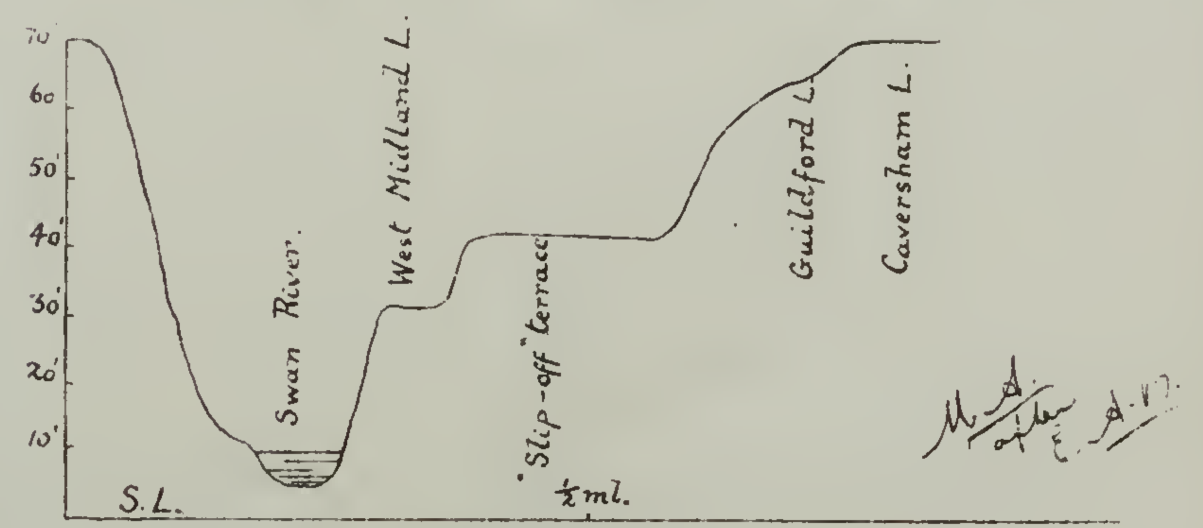

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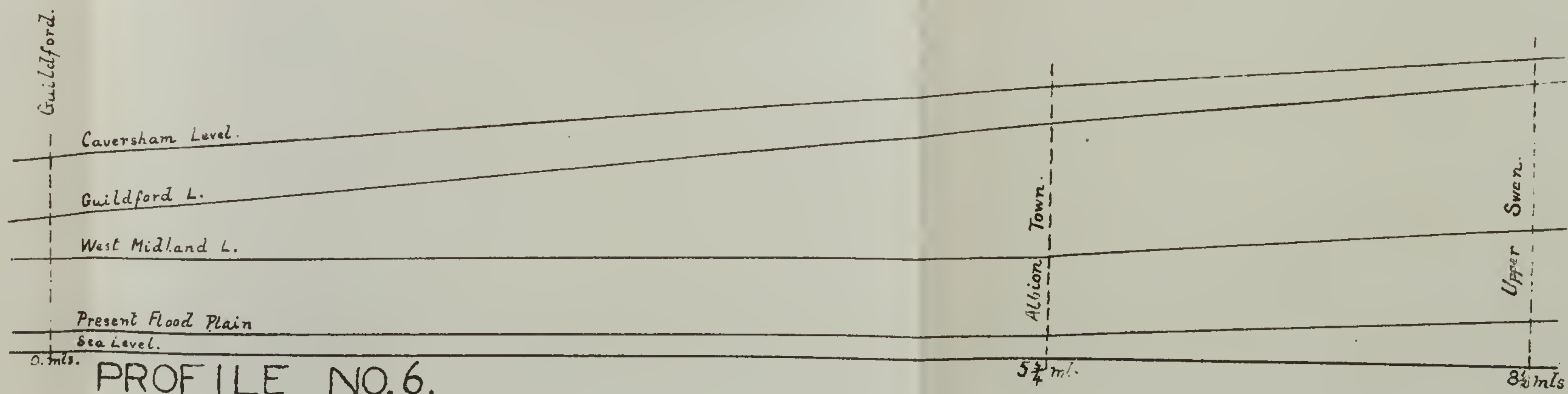

PROFILE NO. 6.

Plate VI.—Marine abrasion at Rottnest.

FISH COLLECTED BY THE GOVERNMENT TRAWLER "PENGUIN," NEAR ALBANY.

By L. GLAUERT, of the W.A. Museum.

(*Read on* 14*th September*, 1920.*)

The Trustees of the Museum have received an interesting collection of fish from Mr. F. Aldrich, the Chief Inspector of Fisheries. These specimens were obtained by the "Penguin" whilst trawling between Bald Island and Haul Off Rock, about 50 miles east of Albany, in water varying from 28 to 32 fathoms.

Family *HETERODONTIDAE.*

Heterodontus philippi (Bloch & Schneider).

This shark, which is well known from the west coast of W.A., was recorded from south of Eucla in the report of the S.A. Government Trawling cruise of 1914. It was not obtained in Western Australian seas by the F.I.S. "Endeavour."

Family *SCYLLIORHINIDAE.*

Scylliorhinus analis Ogilby.

Like the preceding, this deep water Cat Shark was collected south of Eucla in 1914, its first record for Western Australia.

Family *ORECTOLOBIDAE.*

Parascyllium ferrugineum McCulloch.

The Rusty Cat Shark, though known to occur in the waters of South Australia, is now recorded from Western Australia for the first time.

Family *PRISTIOPHORIDAE.*

Paracyllium ferrugineum McCulloch.

The Saw Shark known from South Australia is the closely related species *P. nudipinnis.* The specimen collected off Bald Island appears to be the form found in Eastern Australia though differing from it in coloration. Instead of being uniformly greyish, it is

* By permission of the Trustees of the Museum.

ornamented with alternating plain and spotted bands which are fairly regular on the tail but break up into irregular patches on the fore part of the body. The spots are darker, and the background considerably lighter, than the immaculate bands and areas.

This Saw Shark is a new record for Western Australia.

Family *RAJIDAE.*

Raja waitii McCulloch.

A small male of this species is included in the collection. It is new to the Museum collection and to the fish fauna of the State.

Family *GONORHYNCHIDAE.*

Gonorhynchus greyi (Rich).

A specimen of this burrowing and sand-loving Rat Fish was obtained whilst the trawl was down on a stony bottom.

Family *MONOCENTRIDAE.*

Monocentris gloria-maris De Vis.

Four specimens of this deep sea fish are in the collection. Their presence in shallow water is rather unusual.

Family *ZEIDAE.*

Zeus faber, L.

One small specimen is in the Collection.

Family *SERRANIDAE.*

Callanthias allporti Gunther.

Nine specimens of this gaudy little perch were obtained. Although this is the first record its presence could be assumed as it was known to inhabit the Bight.

Caesioperca lepidoptera (Forster).

This little fish, which bears a superficial resemblance to the preceding, is also now recorded from Western Australian seas for first time.

Family *CARANGIDAE.*

Trachurus novae-zealandiae Hutton.

There are three specimens of the New Zealand Horse Mackerel in the collection. The fish is an addition to the known fish of Western Australia in the Museum.

Family *ENOPLOSIDAE.*

Enoplosus armatus (Shaw).

One specimen is included in the collection.

Family *HISTIOPTERIDAE.*

Zanclistius elevatus (Ramsay & Ogilby).

Two fine specimens of this Long Finned Boar Fish are in the collection. The species was not previously represented in the Museum.

Maccullochia labiosa (Gunther).

This species, which is now recorded from Western Australia for the first time, is represented by three specimens.

Family *OPLEGNATHIDAE.*

Oplegnathus woodwardi (Waite).

One specimen of the Knife Jaw Fish was included among the fish presented to the Museum.

Family *CHILODACTYLIDAE.*

Dachtylosparus macropterus (Forster).

The Jackass Fish, though known to occur in the South Australian portion of the Bight, is now for the first time recorded for Western Australia.

Family *URANOSCOPIDAE.*

Kathetostoma nigrofasciatum Waite & McCulloch.

The type specimen of this Stonelifter was obtained in the Bight, South of Eucla, in 1914, during the South Australian Government Trawling Cruise, in 80-140 fathoms. The range of the fish is now known to extend Westward to Bald Island and into much shallower water. Two specimens were obtained by the "Penguin." It was not previously represented in the Museum collection.

Family *CALLIONYMIDAE.*

Callionymus calauropomus Rich.

The crook-spined Dragonet was collected by the "Erebus" and "Terror" early last century in Western Australian waters, but does not appear to have been noted subsequent to that date among collections of Western Australian fish. Eight specimens are now in the Museum.

Family *SCOMBRIDAE.*

Scomber japonicus Houtt.

This species is represented by five specimens.

Family *SCORPAENIDAE.*

Neosebastes panda McCulloch & Waite.

This Devilfish is new to the Museum collection and an addition to the known fish fauna of the State. The type locality is Spencer's Gulf, South Australia.

Family *TRIGLIDAE.*

Lepidotrigla pleuracanthica (Rich).

This striking little Gurnard is included among the "Erebus and Terror" collection. The type locality is Sydney. It has not previously been recorded for Western Australia, and was not represented in the Museum collection of fish.

Family *OSTRACIONTIDAE.*

Capropygia unistriata Kaup.

Five specimens of this striking little Box fish are in the collection. The species was collected South of Eucla in 1914 on the South Australian Government Trawling Cruise, but was not represented in the Museum.

Anoplocapros gibbosus Waite & McCulloch.

This Box fish was obtained by the South Australian Government Trawler in 1914 in Western Australian waters. The type locality is South of Eucla. Four specimens were trawled by the "Penguin."

Aracana spilogaster Rich.

One specimen of this Boxfish is in the collection.

Tetraodon armilla Waite & McCulloch.

There are three specimens of this fish in the collection. It had previously been collected off Fremantle and in the South Australian portion of the Bight, so that its inclusion among the "Penguin" fish is not remarkable.

A CONTRIBUTION TO THE "CHEMISTRY OF ALUNITE."

By H. BOWLEY,
Assistant Mineralogist and Chemist.

(*Read 14th September*, 1920.*)

The total disappearance of all forms of potash for fertilising purposes from the Western Australian market during the past few years, and the insistent demands of fruit-growers and market gardeners for supplies, have led to an investigation being made of the various potash-bearing minerals of this State in the Geological Survey Laboratory of Western Australia with a view to supplying this need. Many of the results of this investigation have already been published by Dr. E. S. Simpson in an official bulletin "Sources of Industrial Potash in Western Australia."

It has been the author's privilege to more fully investigate the chemical properties of alunite—a basic sulphate of potash and alumina—a mineral which occurs in large quantities in this State and gives most promise of yielding commercial supplies of potash.

The results obtained are of sufficient importance to be set out in detail, both as supplying data as to the chemical properties of the mineral for the information of mineralogists, and as supplying information which, it is hoped, will regulate the practice of using the mineral as a source of potash for agricultural purposes.

A complete isomorphous series of minerals is known, ranging from practically pure $K_2O.3Al_2O_3.4SO_3.6H_2O$ to practicaly pure $Na_2O.3Al_2O_3.4SO_3.6H_2O$. Commercially, any member of this series containing an appreciable amount of potash is known as alunite. Strictly, only those members of the series lying between the pure potash compound and the mineral containing equal molecules of potash and soda would be alunite, whilst an excess of soda molecules over potash molecules would indicate the mineral known as natro-alunite.

The most important deposits of alunite in Western Australia are situated at Kanowna and are dealt with very fully in Bulletin No. 77 of the Geological Survey of W.A. The following remarks

* By permission of the Director of the Geological Survey of Western Australia.

and results apply to experiments, etc., carried out, except when otherwise stated, on the mineral from that locality.

The Kanowna alunite is a white, firm, finely crystalline mass, resembling somewhat in appearance a compact clay, for which it might readily be mistaken. It breaks, when freshly mined, with a typical snap similar to the breaking of a biscuit. After exposure to air for a few days in a comparatively dry atmosphere many specimens of the mineral disintegrate into a fine powder, due to the presence of admixed salts. If allowed to partly dry and then again wetted, it shows a tendency to soften and crumble; this is probably due to partial dehydration and then absorption of water by the colloids (*i.e.*, clay, etc.) present. The mineral is extremely porous and tests carried out on several pieces dried at 80°C. gave 22.0 18.1 and 10.8 per cent. of water absorbed by weight, the air space by volume being 58.3, 48.0 per cent., and 28.6 per cent., respectively.

The powder, under the microscope, appears as minute, colourless, transparent, cubical grains, which have been determined by Dr. Simpson as "not true cubes of the isometric system, but rhombohedrons approximating to cubes." This is shown by their optical properties, the crystals being anisotropic with diagonal extinction. The individual crystals are very minute, ranging in size from 3 to, at the most, 10 microns. The specific gravity was determined in methylene iodide and proved to be very close to that of quartz, viz., 2.65. The refractive index was determined by mounting some of the powder on slides with liquids of known refractive index and examining them under a microscope. The mineral agreed with that of oil of cassia, having a refractive index of 1.58.

The refractive index affords a simple and ready method for the detection of alunite by immersion. The mean refractive indices of minerals resembling alunite in appearance are—

Kaolin	1.54
Quartz	1.547
Sericite	1.587
Calcite	1.601
Magnesite	1.72

The alunite from Kanowna is invariably associated with appreciable amounts of water soluble salts and a little quartz, kaolin and mica.

The empirical formula for alunite is—

$$K_2O, 3Al_2O_3.4SO_3.6H_2O.$$

which may be represented as $K_2SO_4.Al_2(SO_4)_3.4Al(OH)_3$. but for reasons which will be dealt with later, would be more correctly written as $K_2SO_4.3HOAlSO_4.3Al(OH)_3$.

Dr. Simpson suggests the following structural formula for alunite:—

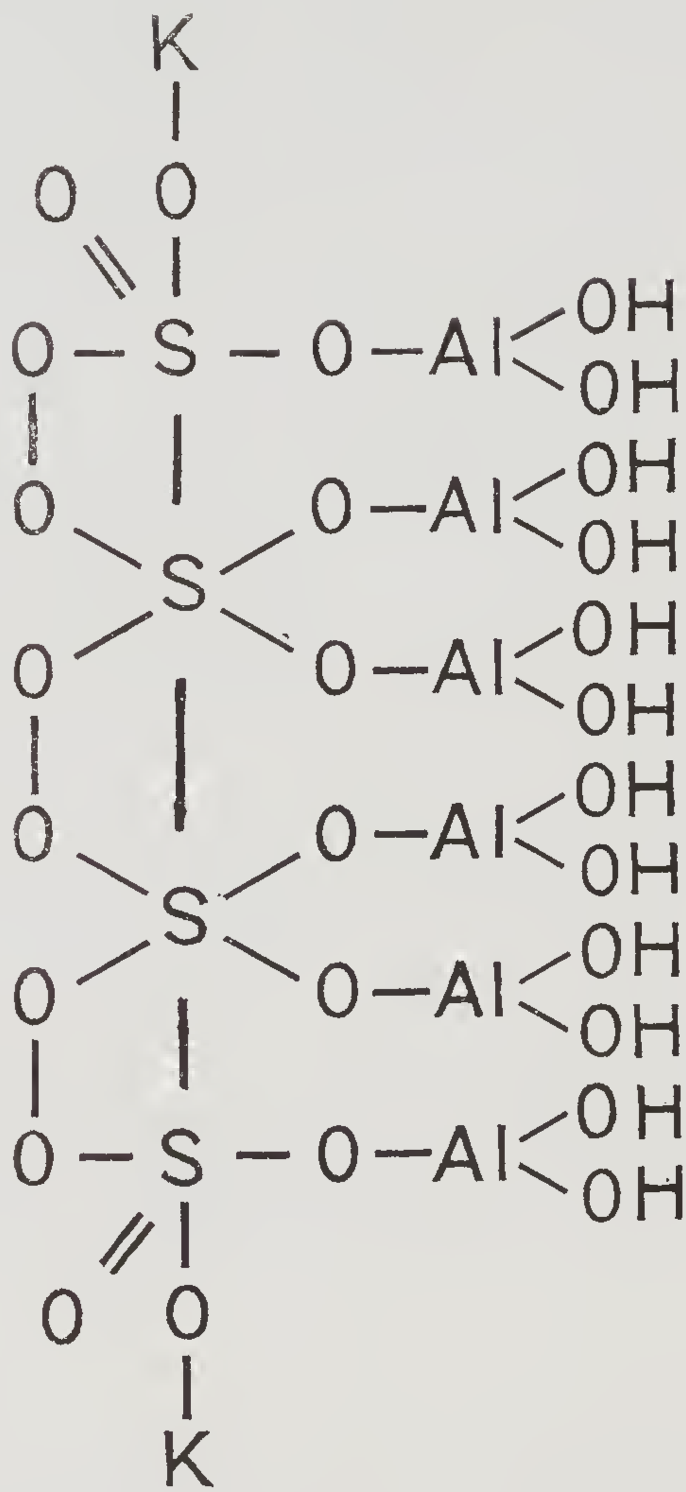

Plate IX.—Structural formula for alunite.

The composition of typical West Australian alunites is given in the accompanying table:—

ANALYSES OF ALUNITE AND NATRO-ALUNITE.

	A. Alunite. Edjudina District.	B. Natro-alunite. G.M.L. 2, Kalgoorlie.	C. Alunite. G.M.L. 1159, Kanowna.	D. Alunite M.L. 12x, Kanowna.	E. Natro-alunite. P.A. 506, Kanowna.	F. Impregnated Clay, G.M.L. 918, Kanowna.	G. Natro-alunite Matrix. P.A. 506, Kanowna.	H. Natro-alunite Matrix. P.A. 506, Kanowna.
	%	%	%	%	%	%	%	%
H_2O+ ...	13·23	15·19	14·55	...	15·45	2·80	2·63	6·70
K_2O ...	8·02	2·46	9·32	7·56	5·42	3·10	2·41	2·19
Na_2O ...	1·54	4·90	2·14	2·56	4·07	·40	1·00	·60
Al_2O_3 ...	33·24	36·23	35·01	...	36·46	13·08	15·17	21·96
SO_3 ...	35·37	36·52	37·84	37·45*	37·64	1·24	·01	·05
Fe_2O_3 ...	·61	1·24	·79	...	·24	·68	·13	·15
MgO ...	None	·15	None	...	None	·36	·15	·03
CaO ...	·24	None	None	...	None	None	None	None
SiO_2 ...	7·40	2·61	·45	...	·95	78·44	77·21	66·94
P_2O_5 ...	·09	·56	...	...	...	...	...	...
TiO_2 ...	...	...	...	...	...	...	·24	·20
H_2O- ...	·32	·33	None	·42	·06	·03	·10	·26
NaCl ...	None†	None†	None†	...	None†	None†	·79	·88
Other soluble Salts ...	None	None	None	...	None	None	·25‡	·25§
	100·06	100·19	100·10	...	100·29	100·13	100·09	100·28
Density ...	...	2·71	2·77	...	...	...	...	...
Analyst ...	H. Bowley.	A. J. Robertson.	H. Bowley.	H. Bowley.	E. S. Simpson.	H. Bowley.	S. Gillies.	S. Gillies.

* Includes 0·13 SO_3 soluble in water. † Washed with water before analysis. ‡ Includes SO_3 0·06. § Includes SO_3 0·08.

EFFECT OF DRY HEAT.

The commercial utilisation of alunite in the past has been based on the formation of potash alum through the dissociation of the mineral by heat and then by wetting the roasted product. The theory of the process needs verification and, in the opinion of the author, the effect of heating alunite is not to form a true alum, but a basic sulphate of alumina and alkalis. The following experiments were carried out with a view to ascertaining the effect of dry heat at varying temperatures:—

100° *Centigrade.*

The sample of alunite (D) used in this experiment was crushed to pass a 30 mesh screen, the major portion passing a 90 mesh. The mineral was dried in a water oven at 98°C. to remove hygroscopic water, cooled, and then weighed: It was then reheated for one hour and again weighed, the loss being equal to 0.01 per cent. It was again placed in the water oven for two hours and the weight again taken, showing a loss of only 0.002 per cent. It is evident, therefore, that at the above temperature, the mineral is practically unaffected.

200° *Centigrade.*

The mineral used in the previous experiment was heated to a temperature of 200°C and weighed; it was again heated for one hour at 200°C, and again weighed. No loss at all was recorded. Alunite is, therefore, unaffected at temperatures up to 200°C.

300° *Centigrade.*

A sample of alunite (D) containing 0.42 per cent. of hygroscopic water was heated to a temperature of 300°C., and showed a loss of 0.49 per cent.

The mineral is, therefore, unaffected at temperatures up to 300°C.

418° *Centigrade.*

One gm. of a sample (D) containing 99 per cent. alunite, was heated in a gas muffle gradually to the temperature of the melting point of pure zinc (418°C.). To prevent any oxidation of the zinc indicators, the metal was enclosed in sealed combustion glass tubes. The heating was stopped as soon as the zinc melted, the charge cooled and weighed. The tests were repeated until a further loss was inappreciable.

The successive losses in per cent. noted were:—2.36 per cent., 3.06 per cent.; 5.80 per cent.; 7.48 per cent.; 8.34 per cent.; 8.95 per cent.; 9.29 per cent.; 9.42 per cent.; 9.63 per cent.; 9.67 per cent.

The total loss recorded was equivalent to 4½ mols. of water, if it was water only, and not a mixture of H_2O and SO_2.

In order to ascertain if any of the sulphur trioxide was volatilised, the residue was dissolved in 5 per cent. caustic soda solution, the sulphur content of which was known, and the sulphur trioxide determined. The results proved that there was no appreciable loss of SO_3.

NaOH soluble SO_3 in raw mineral 37.09 per cent.
NaOH soluble SO_3 in mineral after roasting .. .. 36.96 „

The roasted mineral was readily soluble in lukewarm 5 per cent. NaOH solution, whilst the raw mineral required several minutes on a water oven to complete solution.

The roasted mineral was only very slowly attacked by water, a portion of it dissolving and at the same time producing a voluminous precipitate of aluminium hydrates. A sample of commercial potash alum ignited at the same temperature proved to be fairly readily soluble in warm water and only produced a slight precipitate. The foregoing suggested that, on roasting alunite at the temperatures mentioned, a basic sulphate of aluminium was formed, which, on the addition of water, hydrolysed and precipitated aluminium hydrate. It was considered possible that the precipitate formed may be a basic sulphate of aluminium, but, on dissolving it in hydrochloric acid and adding barium chloride solution, only traces of sulphates were detected.

The reactions taking place at this stage may be expressed thus:—

$$2\,[K_2SO_4\cdot 3HOAlSO_4\cdot 3Al\,(OH)_3\,]\ \text{heated} \longrightarrow$$
Molecular weight. 1658·24.
$$2\ K_2SO_4\cdot 6HOAlSO_4\cdot 3Al_2O_3 + 9H_2O$$
1496·06 162·18

On the addition of water to the roasted product the basic sulphate formed dissociates, precipitating aluminium hydrate, leaving aluminium sulphate in solution, thus:—

$$\underset{\text{Basic aluminium sulphate.}}{6HOAlSO_4} \longrightarrow \underset{\text{Aluminium sulphate.}}{2Al_2(SO_4)_3} + \underset{\text{Aluminium hydrate.}}{2Al(OH)_3}$$

The completed equation for the formation of alum from roasted alunite is—

$$2K_2SO_4 + 2Al_2(SO_4)_3 + 48H_2O \longrightarrow \underset{\text{Potash Alum.}}{4KAl(SO_4)_2\cdot 48H_2O}$$

Alum is not formed by roasting but only by a subsequent series of reactions after the addition of water. It therefore appears that the effect of heat at the above temperature is to remove the water immediately attached to the aluminium, shown in the formula as attached to the potentially free alumina.

525° Centigrade.

Two separate lots of the mineral were then heated in a similar manner to a temperature of 525° C., the melting point of stibnite, a natural sulphide of antimony. The results obtained were as follow :—

	A.		B.
Mineral	2 gms.		1 gm.
		%	%
Loss	·0762 gms.	3·81	9·11
	·0876 ,,	4·38	13·01
	·1632 ,,	8·16	13·04
	·2396 ,,	11·98	
	·2513 ,,	12·565	
	·2569 ,,	12·845	
	·2602 ,,	13·01	
	·2612 ,,	13·06	
	·2616 ,,	13·08	

In the first series the heating was gradual, the test being withdrawn as soon as the indicator melted, weighed, and reheated to the same temperature, the process being repeated until the loss was inappreciable. The test in the second series was allowed to remain in the furnace several minutes after the melting of the stibnite.

The loss found in both cases is equal to the total water present and the residue showed practically no loss of SO_3. The residue was partly soluble in water, forming at the same time a sticky gelatinous mass. On warming the water extract a bulky precipitate of aluminium hydrate was formed. The equations are:—

$$2\,[K_2SO_4 3HOAlSO_4 \cdot 3Al\,(OH)_3]\ \text{heated} \longrightarrow$$
$$2K_2SO_4 + 3\,OAl_2\,(SO_4)_2 + 3Al_2O_3 + 12H_2O.$$

The theoretical loss to satisfy this reaction is 13.04 per cent.

On adding water to the roasted product and warming, aluminium hydrate is precipitated and potash alum formed in solution.

$$3\,OAl_2\,(SO_4)_2 + 3H_2O \longrightarrow 2Al_2\,(SO_4)_3 + 2Al\,(OH)_3$$
$$Al_2\,(SO_4)_3 + K_2SO_4 + 24H_2O \longrightarrow 2KAl\,(SO_4)_2 \cdot 24H_2O.$$

The reactions proved by those experiments differ from those hitherto accepted. Thus Waggaman* states—

on heating to a moderate temperature (500° C.) water is driven off and the mineral decomposes into alumina and potassium sulphate.

He makes no mention of the formation of a basic sulphate of alumina but states, *inter alia*, that, in Italy, for the production of alum

after calcining the ore at low red heat..............it is exposed in the air for several weeks or months, being moistened with water from time to time......... The reactions are represented thus :—

$$(1.)\quad K_2O3Al_2O_34SO_36H_2O \qquad 2KAl\,(SO_4)_2 + 2Al_2O_3 + 6H_2O$$
$$(2.)\quad 2KAl\,(SO_4)_2 + 24H_2O \qquad 2KAl\,(SO_4)_2 \cdot 24H_2O.$$

* U.S. Dept. Agric. Bull. 415, p. 2.

E. Sorel*, whose description of the La Tolfa method of treatment of alunite is the most detailed on record, says:—

The treatment of the alunite rock begins with a very moderate roasting, which by dehydrating the excess of the alumina, renders it insoluble. But it is necessary to be very careful not to push the temperature too far, for the sulphate of aluminium would be partially decomposed and would set free a mixture of sulphurous and sulphuric anhydrides with oxygen.

It is probable, when the proportion of sulphuric acid is greater than that which corresponds to the quantity of alum equivalent to the potash present, that there is formed, under the action of heat, an insoluble basic sulphate of aluminium, $6Al_2O_3 \cdot 2SO_3$†. Under the action of a temperature sufficient to liberate the vapours of sulphuric anhydride, one would obtain potassium sulphate in excess, alum, and a still more basic sulphate of aluminium, $7Al_2O_3 \cdot 5SO_3$.

From the results obtained by the writer, it appears that on heating alunite at temperatures up to 500° Centigrade, free potassium sulphate and a basic sulphate of aluminium are formed and not an anhydrous alum. This would also explain the necessity for exposing the calcined mineral to air and moisture for many weeks for the production of potash alum after calcining at the above temperatures.

801° *Centigrade.*

On heating the mineral to a temperature of 801° C. (melting point of common salt), the whole of the water and three-quarters of the sulphur trioxide is driven off, leaving a residue of potassium sulphate and alumina.

One gram of the mineral heated in a gas muffle at the above temperature gave the following losses:—

(1)	(2)
41.44	41.76

The equation is—

$$K_2SO_4 \cdot 3HOAlSO_4 \cdot 3Al(OH)_3 \longrightarrow K_2SO_4 + 3Al_2O_3 + 3SO_3 + 6H_2O.$$

In this and previous quotations, Na_2SO_4 replaces K_2SO_4 to an extent proportional to the Na which substitutes K in the original mineral.

The theoretical loss to satisfy this equation is 42.0 per cent.

The potassium sulphate formed is readily dissolved in water and the solution shows no tendency to produce a precipitate on warming. With a view to determining the conditions under which the whole of the potassium sulphate could be leached out of the calcined mass, several lots of the alunite ore were calcined under similar conditions and leached with water for varying lengths of time,

* La Grande Industrie Chemique Minerale, p. 716.

† 2 is probably a misprint in the original for 5.

the potash and soda being determined in the filtered extract. The results obtained were:—

(a) Half-gram of mineral, roasted, moistened with 50 cc. cold water and let stand overnight; the solution was decanted off, then 50 cc. of hot water added, warmed for one hour on water bath, filtered and washed with hot water.

(b) Half-gram of mineral, roasted, taken up with 50 cc. hot water, allowed to stand on water bath for one hour with frequent stirring, decanted and retreated for a further hour with 50 cc. water, filtered and washed with boiling water.

(c) Half-gram of mineral, roasted. taken up with 100 cc. hot water and allowed to stand on water bath for 5 hours with occasional stirring, then decanted and treated for a further 3 hours in a similar manner, then filtered and washed.

(d) Half-gram of mineral, roasted, taken up with 50 cc. of water, allowed to stand for one hour on a water bath with frequent stirring, then filtered and washed with boiling water. The residue was then transferred to the beaker and retreated for a further hour under similar conditions, again filtered and washed and then again retreated.

	Potash.		Soda.	
	%		%	
(a.)	4·98		2·92	
(b).	4·96		2·94	
(c.)	5·00		2·90	
(d.) First extract	4·66	5·02	2·76	2·94
Second extract	·36		·18	
Third extract	traces		traces	

These figures show that after calcining the mineral at 800° C. the potassium sulphate formed is very readily soluble in warm water.

Another sample (D) of high grade alunite, giving an ignition loss of 41.44 per cent. gave the following figures:—

	2 hours leaching. 100 cc. water	3 hours leaching. 100 cc. water.
	%	%
$NaCl + KCl$	16·18	16·20
K_2O	7·10	7·10
Na_2O	2·54	2·55

960° *Centigrade.*—To determine the effect of over roasting in the presence of common impurities, one half-gramme lot of a low grade alunite ore was heated to the melting point of silver (960° C.) and the results showed a loss of water soluble potash due to the formation of an insoluble potassium compound, probably a potassium alumino-silicate, by interaction between the first formed

potassium sulphate and the associated silica and silicates. The results obtained were:—

	Calcined at 801° C. %	Calcined at 960° C. %
Ignition loss	29·08	30·54
Water soluble Potash, K_2O	4·02	3·70
Water soluble Soda, Na_2O	2·49	2·22

The increased ignition loss in this case is due to the dissociation of the potassium and sodium sulphates.

SOLUBILITY OF ALUNITE.

The production of water soluble potash from alunite for fertilising purposes by roasting has proved to be a fairly costly process, entailing the employment of an extensive roasting plant. The fuel consumption has been found to be excessive owing to the fact that the reactions taking place are endothermic; and the necessity of keeping the temperature within comparatively narrow limits is a severe tax on the staff.

Owing to the fact that very little information was obtainable showing the solubility of the mineral in various reagents, the following experiments were carried out with a view to ascertaining if some cheaper method could be evolved for rendering the potash available as a plant food.

SOLUBILITY IN WATER.

The only direct references to the effect of water upon alunite which could be found were those of Waggaman and Cullen* and of Janes,† who both say that alunite is "insoluble in water."

In view, however, of the rapid solution of alunite by caustic alkali solution, it appeared probable that its solubility in pure water was appreciable.

The material chosen for this test was soft and porous. It was over 99 per cent. pure, containing K_2O, 7.56 per cent; Na_2O, 2.56 per cent.; the impurities being quartz with traces of kaolin, muscovite, limonite, epsomite and common salt.

This material was crushed to pass a 30-mesh sieve, the major part passing also a 90-mesh sieve. One gramme was placed in a silica beaker, covered with 100 cc. water and stirred at frequent intervals with a platinum rod. At the end of one day the solution was decanted through a small dense filter and the filtrate evaporated to dryness in a weighed platinum dish, dried at 200° C. and weighed. Thereafter the process was repeated four times, the length of standing being increased to two days, but the same gramme of ore and the same filter was used throughout. The temperature ranged from 15° C. to 25° C., an average of 20° C. Owing to the tendency of much of the finest alunite to float on the surface of the water, there should be no doubt as to the saturation of the

* U.S. Dept., Agric. Bull. 415, p. 2.

† Comm. of Aust., Adv. Counc. of Sci. and Ind., Bull. No. 3, p. 9.

solution under these conditions. The weight of the extractions was corrected by a blank on the distilled water used. Owing to the fact that this contained a little organic matter the final weighings were made after heating to a temperature of about 400° C., which was sufficient to drive off this organic matter and dehydrate the alunite taken into solution. The first extract (0.0048 gm.) contained the greater part of the associated epsomite and salt. The second extract contained a little, and the third probably traces, but the fourth and fifth should not have been contaminated. The solubilities shown by these two were, in 100 cc.

4th 0.0003 grammes.
5th 0.00025 „

The mean solubility, therefore, of alunite in 100 cc. of pure water at 20° C. is 0.00027 grammes.

This is of the same order as that of barite ($BaSO_4$), which is 0.00023 grammes.

SOLUBILITY IN CAUSTIC ALKALIS.

No mention is made by Dana and Lecroix, two well recognised authorities on mineralogy, of the effect of solutions of KOH and NaOH upon alunite. Janes* says "It is readily soluble in caustic alkalis."

The material used in these experiments was 99 per cent pure, containing 7.56 per cent. K_2O and 2.56 Na_2O, the impurities being a little quartz, kaolin, and water soluble sulphates.

One half gramme lots of the mineral were treated with different strengths of NaOH solution for varying lengths of time and at different temperatures, being stirred well from time to time. The solutions were then filtered and washed well with hot water; the filtrates were just acidified with hydrochloric acid, boiled to expel any CO_2 present, then sufficient barium chloride added and the solutions allowed to stand for a few hours. The barium sulphate was filtered off and weighed and calculated as SO_3.

The SO_3 was determined in a blank on the reagents used and the SO_3 found plus the water soluble sulphates present in the mineral deducted from the total. The SO_3 dissolved was then calculated as alunite from a factor found by determining the total insoluble SO_3 in the sample. The figures obtained were as follow:—

Alunite taken.	Sodium in Solution.	Solution. cc.	Temperature.	Time.	Alunite dissolved. %
1 per cent. NaOH Solution.					
0·5gm.	0·2875	50	20° C.	2 hrs.	19·2
0·5gm.	0·2875	50	20° C.	4 hrs.	30·4
0·5gm.	0·2875	50	91° C.	2 hrs.	98·6
5 per cent. NaOH Solution.					
0·5gm.	1·4375	50	20° C.	2 hrs.	84·3
0·5gm.	1·4375	50	91° C.	20 mins.	100·0

* Comm. of Aust., Adv. Counc. of Sci. and Ind., Bull. No. 3.

The equation for this reaction is:—

$$K_2SO_4 \cdot 3HOAlSO_4 \cdot 3Al(OH)_3 + 12NaOH \longrightarrow K_2SO_4 + 3Na_2SO_4 + 3Na_2Al_2O_4 + 12H_2O$$

The whole of the products of this reaction are water soluble. The results show that alunite is readily dissolved by warm dilute solutions of caustic alkalis, a process which provides a most satisfactory method for getting the mineral into solution.

The effective agent in this reaction is the high concentration of hydroxyl ion which produces aluminate ion at the expense of the basic aluminium salt.

A. J. Robertson's experiments on Kalgoorlie natroalunite, made in the Geological Survey Laboratory in 1915, showed that this mineral passed wholly into solution on warming for 20 minutes with 5 per cent. KOH solution.

SOLUBILITY IN SODIUM CARBONATE.

No references were obtained showing the effect of sodium carbonate solutions on alunite. Knowing that caustic alkalis exert a very rapid solvent effect, and that sodium carbonate hydrolyses freely in water, experiments were carried out with a view to determining the solubility of alunite in sodium carbonate.

The solution used in these experiments contained the same amount of sodium as that in the case of the caustic soda tests. The temperature and time of experiment were also the same, so that the results as to rate of solubility would be comparable. The material also was that used in the caustic soda tests and was treated in exactly similar manner.

1.325 per cent. Na_2CO_3 Solution.

Alunite.	Sodium in Solution.	Solution.	Temperature.	Time.	Alunite dissolved.
		cc.			%
0·5gm.	0·2875	50	20° C.	2 hrs.	0·13
0·5gm.	0·2875	50	20° C.	4 hrs.	0·35
0·5gm.	0·2875	50	91° C.	2 hrs.	43·85

6.625 per cent. Na_2CO_3 Solution.

0·5gm.	1·4375	50	20° C.	2 hrs.	1·09
0·5gm.	1·4375	50	91° C.	2 hrs.	71·60

It will be noted that Na_2CO_3 has very little effect on alunite in the cold, but the attack is considerably increased in warm solutions. From this it is apparent the solubility is due to the hydroxyl ions present, the Na_2CO_3 hydrolysing to form NaOH and H_2CO_3. The reaction may be expressed thus:

$$Na_2CO_3 + HOH = NaHCO_3 + NaOH = 2Na^+ + (HCO_3)^- + (OH)^-$$
$$NaHCO_3 + HOH = NaOH + H_2CO_3 = Na^+ + (OH)^- + H_2CO_3$$

SOLUBILITY IN CAUSTIC LIME SOLUTIONS.

In view of the rapid and complete solution of alunite in caustic alkalis, and to obtain a cheaper and more readily available solvent, the effect of caustic lime solutions, which also contain a considerable concentration of hydroxyl ion, were tried on the mineral.

The material used for the preliminary tests was 99 per cent. pure, containing K_2O, 7.56 per cent.; Na_2O, 2.56 per cent. The impurities were mainly quartz and kaolin with small amounts of epsomite and salt.

Several gramme lots of the mineral were placed in quartz beakers with 100 cc. of water and 0.25 gm. of freshly burnt lime. The solutions were stirred occasionally and allowed to stand in the cold for periods of one, two, and eight days. The solutions were then filtered and the potash and soda estimated in the extract. It was noticed after one day that a bulky gelatinous precipitate was formed, quite distinct in appearance from the original alunite. This proved on examination to be calcium aluminate. The results obtained were—

	Potash. %	Soda. %
Originally in Sample	7·56	2·56
In solution after one day's treatment	0·71	1·15
In solution after two days' treatment	1·09	1·26
In solution after eight days' treatment	1·16	1·45

These figures were considered so satisfactory that arrangements were made to carry out a systematic series of experiments, the results of which are shown below.

These tests were carried out on three separate lots of the mineral containing the following amounts of—

	1	2	3
Alunite	95·05	96·55	97·31
Total Potash	6·46	8·54	7·98
Total Soda	3·62	2·24	2·60

The samples were crushed to pass a 30-mesh sieve, the greater portion of which would pass a 90-mesh sieve. One half gramme of the mineral was placed in a resistance flask with 400 cc. of a freshly prepared solution containing the amount of calcium hydrate shown in the table. (The solubility of $Ca(OH)_2$ in water is 1.7 gms. per litre.) Several pieces of glass rod were placed in the flask which was then tightly stoppered with a waxed cork and the tests shaken vigorously from time to time. At the expiration of the time allowed the precipitate was filtered off, well washed with hot water, and the potash and soda which had passed into solution estimated by the platinic-chloride method.

It was noticed that in the case of treatment with caustic alkalis the alunite goes completely into solution, but with caustic lime a bulky precipitate was formed. This precipitate was examined after

washing well to remove all the calcium sulphate, and found to consist of calcium aluminate and undecomposed alunite.

The results shown in Table I. were obtained by treating the 0.5 gm. of the mineral with 0.5308 gms. of caustic lime, which is considerably more than necessary to satisfy the following equation, the theoretical quantity being 0.2029 gms. of CaO or 0.2679 $Ca(OH)_2$.

$$K_2SO_4 \cdot 3HOAlSO_4 \cdot 3Al(OH)_3 + 6Ca(OH)_2 \longrightarrow K_2SO_4 + 3CaSO_4 + 3CaAl_2O_4 + 12H_2O.$$

KANOWNA ALUNITE.

DIGESTION EXPERIMENTS WITH LIME.

SERIES I.—TEMPERATURE, ATMOSPHERIC.

Sample No.	Lease and Grade of Alunite.	Ore taken.	Solution used.	$Ca(HO)_2$ in Solution.	Time of Digestion.	Dissolved Alkalies K_2O.	Dissolved Alkalies Na_2O.	Dissolved % of Total Potash.	Dissolved % of "Extractable" Potash.
		gms.	cc.	%	Days.	%	%		
5811E	McKinley & party, "Shamrock," M.L. 12, 95·05 %	0·50	400	0·1327	1	2·97	2·03	46·0	47·2
,,	,, ,,	,,	,,	,,	2	3·87	3·41	59·0	61·5
,,	,, ,,	,,	,,	,,	3	5·21	(3·09)	80·6	82·8
,,	,, ,,	,,	,,	,,	4	5·51	3·44	85·3	87·6
,,	,, ,,	,,	,,	,,	7	5·77	(3·03)	89·3	91·7
,,	,, ,,	,,	...	...	"Extractable"*	6·29	3·11	97·4	...
,,	,, ,,	,,	...	...	Total	6·46	3·62	100·0	...
5824E	Emde & Curran's "Breakaway," 96·55%	0·50	400	0·1327	1	2·47	1·18	28·0	29·1
,,	,, ,,	,,	,,	,,	2	3·97	1·70	46·5	46·8
,,	,, ,,	,,	,,	,,	3	5·53	2·20	64·7	62·5
,,	,, ,,	,,	,,	,,	4	6·29	2·23	73·8	74·3
,,	,, ,,	,,	,,	,,	7	6·87	2·24	80·5	81·0
,,	,, ,,	,,	...	...	"Extractable"*	8·48	2·07	99·3	...
,,	,, ,,	,,	...	...	Total	8·54	2·24	100·0	...
5825E	Fletcher & party, P.A. 518, 97·31 %	0·50	400	0·1327	1	2·46	1·46	30·8	31·3
,,	,, ,,	,,	,,	,,	2	5·57	1·84	68·5	69·5
,,	,, ,,	,,	,,	,,	3	6·59	2·24	82·6	83·7
,,	,, ,,	,,	,,	,,	4	6·93	2·38	86·8	88·1
,,	,, ,,	,,	,,	,,	7	7·10	2·46	89·0	90·2
,,	,, ,,	,,	...	...	"Extractable"*	7·87	2·56	98·6	...
,,	,, ,,	,,	...	...	Total	7·98	2·60	100·0	...

* Soluble in water after calcining the mineral at 800° C.

The above figures proved that almost saturated but still weak (one-fiftieth normal) solution of $Ca(OH)_2$ under suitable conditions, completely decomposes alunite, all the potash going into solution.

A second series of tests were then carried out to ascertain the effect of still more dilute solutions of caustic lime on the mineral. The amount of $Ca(OH)_2$ in this approximately centinormal solution was far below that required for a saturated solution and slightly more than was necessary to satisfy the foregoing equation.

It will be seen that the quantity of mineral used in this series of experiments was 0.45 gms. as against 0.5 gms. in the first series. This was only a matter of convenience in keeping the bulk of caustic lime solution at 400 cc., at the same time giving an appreciable amount of $Ca(OH)_2$ over that required by theory. The amount of caustic lime used was equal to 0.3152 gms. for 0.5 gms. of alunite, which is 0.0493 gms. excess of the amount required to satisfy the equation shown above.

KANOWNA ALUNITE.

Digestion Experiments with Lime.

Series II., Temperature Atmospheric.

Sample No.	Lease and Grade of Alunite.	Ore taken.	Solution used.	$Ca(HO)_2$ in Solution.	Time of Digestion.	Dissolved Alkalies. K_2O.	Dissolved Alkalies. Na_2O.	Dissolved per cent. of Total Potash.	Dissolved per cent. of "Extractable Potash."
		gms.	cc.	%	Days.	%	%		
5811E	McKinley & Party, "Shamrock," 95·05 %	0·45	400	·0714	1	2·24	2·05	34·7	35·6
"	" "	"	"	"	2	2·67	2·57	41·3	42·4
"	" "	"	"	"	3	2·85	2·63	44·1	45·3
"	" "	"	"	"	4	3·38	2·64	52·3	53·7
"	" "	"	"	"	7	3·36	2·27	52·0	53·4
"	" "	0·50	...	...	"Extractable" *	6·29	3·41	97·4	...
"	" "	"	...	...	Total	6·46	3·62	100·0	...
5824E	Emde & Curran's, "Breakaway," 96·55%	0·45	400	·0714	1	3·28	1·78	38·4	38·7
"	" "	"	"	"	2	3·86	2·00	45·2	45·5
"	" "	"	"	"	3	4·01	2·11	47·0	47·3
"	" "	"	"	"	4	4·52	1·73	52·9	53·3
"	" "	"	"	"	7	4·88	2·04	57·1	57·5
"	" "	0·50	...	...	"Extractable" *	8·48	2·07	99·3	...
"	" "	"	...	...	Total	8·54	2·24	100·0	...
5825E	Fletcher & Party, P.A. 518, 97·31 %	0·45	400	·0714	1	2·67	1·56	33·5	34·0
"	" "	"	"	"	2	3·41	1·78	42·7	43·2
"	" "	"	"	"	3	3·77	2·44	47·2	47·9
"	" "	"	"	"	4	4·17	2·45	52·3	53·0
"	" "	"	"	"	7	4·28	1·65	53·6	54·4
"	" "	0·50	...	...	"Extractable" *	7·87	2·56	98·6	...
"	" "	"	...	...	Total	7·98	2·60	100·0	...

5825E Special—83 gms. ore mixed into a thick paste with 38 gms. 90% lime, allowed to stand 32 days, diluted and filtered; filtrate contained 30·9% of total Potash. * Soluble in water after calcining the mineral at 800° C.

It is highly probable that if facilities be available for the removal of the end products of the reaction as they are formed, the solubility of the mineral would be considerably increased.

In order to ascertain the solubility of alunite in lime with minimum amount of water, an experiment was carried out on 1lb. (453 grams) of alunite containing K_2O, 7.84 per cent.; Na_2O, 2.72 per cent., crushed to pass a 10-mesh screen, mixed with ½lb. (226 grams) lime (CaO) and one gallon of water. It was allowed to stand for two days with occasional stirring and then filtered, the solution being evaporated to small bulk to remove the calcium sulphate, again filtered and evaporated to dryness. The yield of crude potassium and sodium sulphates was 0.1205lbs. (54.6 grams), equal to 70.1 per cent. of the potash and soda present in the ore.

These results are of the greatest value in the utilisation of alunite as they indicate a cheap and ready method for converting the potash of the mineral into a readily available form, and I commend them to the serious consideration of agricultural chemists.

SOLUBILITY IN CALCIUM CARBONATE SOLUTION.

No record could be found of the effect of calcium carbonate on alunite. Owing to the highly satisfactory results obtained by the treatment with caustic lime solutions and also to the fact of the general use of carbonate of lime in agriculture, it was considered advisable to carry out a systematic series of tests with solutions containing calcium carbonate. The solubility of calcium carbonate in water is very low, but calcium carbonate in solution hydrolyses, forming calcium hydrate and calcium bicarbonate, both of which have a greater solubility in water than normal calcium carbonate, but are included in the solubility, viz., 0.013 grams per litre, of $CaCO_3$ in water.

The mineral in each case was placed in flasks with 400 cc. of water and 0.716 gms. of pure precipitated calcium carbonate added; the flasks were stoppered with waxed corks and kept closed during

the whole time of the extraction. The tests were shaken vigorously from time to time. The results obtained are shown in Table III.

KANOWNA ALUNITE ORE

DIGESTION EXPERIMENTS WITH CALCIUM CARBONATE

SERIES III. TEMPERATURE, ATMOSPHERIC.

Sample No.	Lease and Grade.	Amounts used.			Time of Digestion.	Dissolved Alkalies.		Dissolved % of Total Potash.	Dissolved % of "Extractable Potash."
		Ore.	$CaCO_3$.	Distilled Water.		K_2O.	Na_2O.		
		gms.	gms.	cc.	Days.	%	%		
6153E (5811)	McKinley and Party. Shamrock M.L. 12, 95·05 per cent.	0·50	0·716	400	1	0·34	0·42	5·3	5·4
	,, ,,	,,	,,	,,	2	0·44	0·42	6·8	7·0
	,, ,,	,,	,,	,,	3	0·30	0·40	4·6	4·8
	,, ,,	,,	,,	,,	4	0·44	0·48	6·8	7·0
	,, ,,	,,	,,	,,	7	0·46	0·54	7·1	7·3
	,, ,,	,,	,,	,,	"Extractable *"	6·29	3·41	97·4	...
	,, ,,	,,	,,	...	Total	6·46	3·62	100·0	...
6154E (5824)	Emde & Curran's "Breakaway" 96·55 per cent.	0·50	0·716	400	1	0·30	0·34	3·5	3·5
	,, ,,	,,	,,	,,	2	0·32	0·54	3·7	3·8
	,, ,,	,,	,,	,,	3	0·34	0·62	4·0	4·0
	,, ,,	,,	,,	,,	4	0·48	0·68	5·6	5·7
	,, ,,	,,	,,	,,	7	0·60	0·76	7·0	7·1
	,, ,,	,,	...	...	"Extractable"*	8·48	2·07	99·3	...
	,, ,,	,,	...	...	Total	8·54	2·24	100·0	...
6155E (5825)	Fletcher and Party, P.A. 518 97·31 per cent.	0·50	0·716	400	1	0·20	0·38	2·5	2·5
	,, ,,	,,	,,	,,	2	0·30	0·40	3·8	3·8
	,, ,,	,,	,,	,,	3	0·40	0·46	5·0	5·1
	,, ,,	,,	,,	,,	4	0·42	0·40	5·3	5·3
	,, ,,	,,	,,	,,	7	0·44	0·46	5·5	5·6
	,, ,,	,,	...	...	"Extractable."*	7·87	2·56	98·6	...
	,, ,,	,,	,,	...	Total	7·98	2·60	100·0	...

* Soluble in water after calcining the mineral at 800° C.

The results are highly satisfactory in that they show that the alunite is attacked by solutions containing calcium carbonate, potassium sulphate going into solution. The action is considerably slower than that of caustic lime solutions, but there is little doubt that in time the effect would be the same as that of calcium hydrate

solutions. It is considered that had facilities been given for the removal of the free carbonic acid formed in these experiments, the reaction would have been considerably accelerated as the hydrolysis of the calcium carbonate would have been increased.

SOLUBILITY IN HYDROCHLORIC ACID.

Very few authorities give any information regarding the effect of hydrochloric acid upon alunite.

Rammelsberg*, however, referring to true alunite, says: "Is dissolved with difficulty by hydrochloric acid." Janes†, on the contrary, says: "Alunite is insoluble in hydrochloric acid."

As long ago as 1914 Mr. A. J. Robertson proved in the Geological Survey Laboratory that the natroalunite from the Maritana Lease at Kalgoorlie was quite appreciably attacked by warm hydrochloric acid, and that in fact, it was attacked approximately with the same rapidity as crystalline haematite. The results obtained by him on Sample "B," quoted previously, containing 36.52 per cent. of SO_3 with 4.90 per cent. of Na_2O and 2.46 per cent. of K_2O, are as follows:—

Sulphur trioxide passed into Solution.	Method of Solution.	Time.	Nature of insoluble Residue.
		min.	
1·35	Warmed with 5E HCl	10–15	White.
3·52	Warmed with 10E HCl	10	White.
6·52	Warmed with 10E HCl	20	White.
20·38	Boiled with 10E HCl	30	White.
36·52	Warmed with 5% KOH	30	Brown coloured residue and silica.

Later experiments carried out on Kanowna alunite samples, containing 37.32 per cent. of sulphur trioxide gave the following figures:—

Sulphur trioxide passed into Solution.	Temperature.	Time.	Strength of HCl.
%		min.	
0·33	70–75° C.	10	5E
0·11	75° C.	10	10E
0·49	75° C.	20	10E
4·56	100° C.	30	10E

* Rammelsberg, C. F.—Handbuch der Mineralchemie, 1875, p. 274.

† Janes, F. W.—The Alunite Deposits of Australia and their utilisation, 1917, p. 9.

SOLUBILITY IN HYDROFLUORIC ACID.

No reference could be found to the effect of hydrofluoric acid on alunite.

Owing to the close resemblance in many respects of alunite to kaolin, for which it may be mistaken, the effect of that reagent was tried to determine if this acid could be used to distinguish between the two minerals.

The mineral used for these experiments was the same as used for the solubility in caustic soda solutions, being 99 per cent. pure.

The experiments were carried out in platinum vessels and stirred from time to time. 0.5 gm. lots of the mineral were taken and the acid used in each case was equal to 5 cc.. 25E hydrofluoric acid, the results being:—

Strength of Acid.	Time.	Temperature.	Alunite in Solution.
	min.		
5E	15	90° C.	Complete.
10E	30	20° C.	Little.
10E	5	90° C.	Complete.

The solution of the mineral in warm hydrofluoric acid is therefore very rapid. The solution contains a mixture of potash alum and aluminium fluoride.

SOLUBILITY IN SULPHURIC ACID.

Only one reference was found regarding the effect of sulphuric acid on alunite. James, in referring to the effect of acids on alunite, says: "Is soluble in strong sulphuric acid on heating."

The mineral on which these experiments were carried out was 99 per cent. pure, with 2.46 per cent. K_2O and 4.90 per cent. Na_2O. The results obtained were as follow:—

Strength of Acid.	Time.	Temperature.	Alunite in Solution.
5E	1 hr.	90° C.	Trace.
10E	1 hr.	90° C.	Little.
36E	1 hr.	90° C.	Much.
36E*	10 min.	200° C.	Complete.

* It was found that on cooling the solution anhydrous sulphates were thrown out of solution.

CONCLUSIONS.

(1.) Alunite is unaffected by dry heat at temperatures up to 300° C.

(2.) The decomposition of the mineral in alum roasting is in two stages. At 400° C. the mineral loses four and a half molecules of water with the formation of a basic sulphate of aluminium and potash, and on further heating to a temperature of 500° C., the remaining water is removed, forming an anhydrous basic sulphate. On the addition of water the basic sulphates dissociate, producing a true alum and precipitating aluminium hydrate.

(3.) Alunite heated to a temperature of 800° C. dissociates completely into potassium sulphate, alumina, sulphur trioxide and water. Part of the sulphur trioxide dissociates further into a mixture of sulphur dioxide and oxygen.

(4.) On heating alunite to a temperature of 960° C., the potassium sulphate formed is dissociated and interacts with the alumina to form soluble potassium aluminate, or, in the presence of silica, insoluble potassium alumino-silicates.

(5.) Alunite is readily soluble in warm dilute solutions of caustic alkali, hydrofluoric acid, and hot strong sulphuric acid.

(6.) Alunite is slowly soluble in cold solutions of sodium carbonate, but readily soluble in warm solutions of that reagent.

(7.) Alunite is moderately soluble in hydrochloric acid and warm dilute sulphuric acid.

(8.) Alunite is sparingly soluble in water.

(9.) Alunite is attacked fairly readily by a solution of caustic lime, the whole of the potash passing into solution.

(10.) Alunite is appreciably attacked by calcium carbonate solutions.

I wish to express my deep appreciation to my Chief, Dr. E. S. Simpson, who has given me every encouragement to pursue these investigations, for the great interest he has taken in this work, and the way in which he has at all times been ready to assist me with suggestions and give advice when it was most urgently needed. I wish to thank Mr. E. M. Joll for his careful work and interest shown in carrying out the digestion experiments with caustic lime and calcium carbonate. I also wish to acknowledge the courtesy of the Hon. the Minister for Mines in giving permission to publish the figures shown in Tables I., II., and III.

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CONTRIBUTIONS TO THE FLORA OF W.A., No. 2.

By D. A. Herbert, M.Sc., Economic Botanist and Pathologist, Analytical Department, Perth.

Read September 14th, 1920.

Proteaceae.

Conospermum suaveolente, sp. nov.

An erect, rigid scrub, attaining three feet (occasionally more) the upper branches pubescent; leaves glabrous, except for a minute pubescence at the base, numerous, from ½ to 1 inch long, terete, acute, but not pungent, the upper ones becoming linear-terete and suddenly dilated at the base, the dilated portion cuneate, 1 line broad and 1½-2 lines long; flowers blue, in axillary spikes, about 3 lines long, much shorter than the lower leaves, but equalling the younger and shorter leaves of the tips, perianth 3-3½ lines long; perianth-segments minutely pubescent, the upper concave lip as broad as but slightly shorter than the other three lobes, which are shortly united to form the lower lip; lips as long as the tube.

Locality: Kelmscott.

Collector: D. A. Herbert.

Date: August 15th, 1920.

The new species has its nearest affinity in *C. amoenum, Meissn.,* to which it is very closely allied. It differs in the longer and more slender terete leaves, the dilated leaf bases in the upper ends of the branches, and the length of the spike.

The specific name is in allusion to the odour of the flowers. A field examination of several hundred of these plants showed the characters to be constant, with no gradations leading to *C. amoenum.* The spikes are axillary along the stem and do not show the same tendency, as in *C. amoenum,* to cluster at the top.

The older leaves soon fall off, leaving the lower parts of the stem bare and scarred. The constant form is that of a rigid, erect shrub, but a big, old plant may become very straggling, with branches up to 5 feet long.

Leguminosae.

Psoralea pinnata, L.

This is a tall ornamental shrub, native of South Africa, found growing through the swamps round Albany. It is known as *Taylorina*, having been introduced by a man named Taylor. It is well established as a naturalised alien, and is holding its own against the native vegetation. Owing to this, it might be collected as a native plant.

Orchideae.

Caladenia flava, R. Br.

Addition to original description.

Flowers varying from yellow to magenta.

Specimens obtained in September, 1920, at Murray River, Pinjarra, by Mr. J. Clark, are deep magenta, but otherwise their structure is that of the typical *C. flava*. Specimens showing a broad red line on the dorsal sepal and petals are common in the hills. Pinjarra specimens show all gradations from the yellow to the magenta, and can hardly be regarded as being a distinct variety. Intermediate forms are white speckled with magenta. The name *Caladenia flava* is unfortunate, as in the extreme forms there is no trace of yellow.

Irideae.

Romulea Columnae, Sebastiani and Mauri.

An introduced species from the Mediterranean, found amongst Guildford Grass (*Romulea Bulbocodium*) at South Perth, September, 1920. The flowers are pale violet, so it is easily distinguished from the common species.

Fungi.

Polyporeae.

Polyporus Mylittae, Cooke and Massee.

Denmark, received 16/9/20, from S. M. Darragh.

This fungus produces underground sclerotia, which were used by the natives as an article of food, from which fact they received the name Blackfellow's Bread. The fructification is seldom produced. This specimen was about three inches in diameter, but others are said to have attained the size of a football. It is found in all the other States, but has not previously been recorded from Western Australia, though from the account of residents the sclerotia are fairly often ploughed up at Denmark.

NOTES ON STAUROLITE FROM THE MOGUMBER DISTRICT.

By Edward S. Simpson, D.Sc., B.E., F.C.S.

(*Read November 9th*, 1920.)

Staurolite, $H(Fe,Mg)(Al,Fe)_5Si_2O_{13}$, is a comparatively rare metamorphic mineral hitherto recorded from but few localities in Australia. Anderson, in his Bibliography of Australian Mineralogy, gives no locality for it in Victoria, Northern Territory or Tasmania, one only in New South Wales, and two each in Queensland and South Australia.

The existence of this mineral in a belt of country lying somewhere to the north-east of Gingin has been known since 1915, when a parcel of small (4 to 10 mm.) crystals collected from gravel in the valley of Chittering Brook (Brockman River) were submitted to the writer for determination. The more perfect of these showed a combination of the faces $m^1(110)m^2m^3m^4b^1(010)b^2$. There were imperfect indications of occasional twinning on $z(232)$.

Later, in 1917, a single large water-worn crystal was seen which was said to have come from about 13 miles N.E. of Gingin, *i.e.*, between Cullalla and Wannamal, and not far from the head of Chittering Brook, Mogumber being about 22 miles N.N.E. of Gingin. This crystal was a combination of $m^1(110)m^2m^3m^4b^1(010)b^2c^1(001)$. It was 5 cm. in length with a maximum diameter of 4.5 cm. From the same locality came a boulder of rock composed of granular quartz and staurolite, the latter predominating, and occurring in grains of about 1 mm. diameter.

Last year was seen for the first time the probable matrix from which these loose crystals were derived. This is a rock found between Mogumber and Gillingarra. It is fairly uniform in texture, consisting of a ground mass of small scales of muscovite and grains of quartz, in which are embedded numerous large crystals of staurolite and biotite. Of the two coarser constituents staurolite is by far the more common, and is rather evenly distributed throughout this particular specimen. It is in prismatic crystals of a dark brown colour ranging from 1 to 5 millimetres in diameter, and 5 to 30 millimetres in length. The larger sized crystals are infrequent. Twinning has been observed on $z(232)$ but is rare.

Quite recently a fine suite of specimens of this rock was obtained. These are of the same general type as that just described,

but many of the staurolite crystals are much larger, reaching 2 cm. in diameter and 5 cm. in length. The matrix is seen under the microscope to be mainly muscovite in moderately coarse flakes with minor amounts of quartz, chlorite and biotite. Small granules of a black iron ore are abundant and occasional very large biotite crystals. The embedded staurolite crystals show the typical pronounced pleochroism from pale yellow (X,Y) to reddish brown (Z), with high refractive index and biaxial figure. The smaller staurolites (2 mm.) in the section cut are mostly quite free from inclusions, but some carry a large number of the black iron ore granules. The total lack of quartz inclusions is unusual, as Van Hise draws attention to "the absence of inclusions of the iron-bearing constituents of the schists in garnet and staurolite, and the presence of abundant quartzose particles."*

Macroscopically the staurolite is seen to be dark brown in colour, well crystallised, and of all sizes, from 1 to 20 mm. in diameter, some crystals being short and stout, others long and thin. The faces $m^1(110)m^2m^3m^4b^1(010)b^2$ are seen on all, and $r^1(101)r^2$ on many. Twins on z(232) are fairly common even with the largest crystals. The measured angles b^1m^1,m^1m^4,m^1r^1, and r^1r^2 agree closely with those calculated. A cleavage parallel to b is distinct.

The staurolite is very unevenly distributed through the rock and is without definite orientation.

Regarding the origin of the Mogumber staurolite: This mineral is usually developed by thermal metamorphism of a non-calcareous sediment at a high pressure but comparatively low temperature, as indicated by the combined water present. Chloritoid, a mineral very similar in composition and origin to staurolite, is found in nature under practically identical conditions. The causes which lead to the formation of the one mineral rather than the other have not yet been explained, and can only be elucidated by a close study of the occurrences of both minerals. Other closely related metamorphic minerals are garnet and chlorite. Van Hise says of the origin of staurolite (Metamorphism, p. 327) :—

"Staurolite is similar in its occurrence to garnet, but apparently requires more intense metamorphic action for it to begin to form. Its most widespread occurrence is in the schists and gneisses of sedimentary origin. It also develops in profoundly metamorphosed rocks of eruptive origin, but it is not known as an original constituent in any eruptive rock. Like garnet, it may be abundantly developed in the zone of anamorphism in rocks which are cut by intrusives. The conditions favourable to its formation are therefore similar to those which produce garnet (see pp. 300-302) and such minerals as tourmaline, andalusite, sillimanite, and cyanite, with

* Treatise on Metamorphism, p. 701.

which it is associated. It is evidently a mineral which derives its materials from various other minerals, the elements being re-combined into the more compact form of staurolite under deep-seated conditions."

The densities and compositions of the four genetically related minerals Prochlorite, Chloritoid, Staurolite, and Almandine, are:—

Mineral.	Composition.	Water. %	Density.	Molecular* Volume.
Prochlorite	$x\,2H_2O \cdot 3(Fe, Mg)O \cdot 2SiO_2 +$ $y2H_2O \cdot 2(Fe,Mg)O(Al,Fe)_2O_3 \cdot SiO_2$	10–12	2·95	114†
Chloritoid ...	$H_2O \cdot (Fe, Mg)O \cdot (Al, Fe)_2O_3 \cdot SiO_2$	6–7	3·55	69
Staurolite ...	$H_2O \cdot 2(Fe,Mg)O \cdot 5(Al,Fe)_2O_3 . 4SiO_2$	1–2	3·70	122 (or 244)
Almandine ...	$3(Fe,Mg)O \cdot (Al,Fe)_2O_3 \cdot 3SiO_2$	none	4·05	117

From these figures one is led to the conclusion that temperature and pressure play a large part in determining which species is generated by the metamorphism of a given rock containing the materials required. It is evident that at the lowest temperatures and pressures prochlorite would tend to form; at higher temperatures but moderate pressures, staurolite. On the other hand, at high pressures and moderate temperatures, chloritoid would develop, whilst at the highest temperatures with moderately low pressures, almandine garnet would form. *See* Plate XIII.

The data for Iolite, a very similar mineral found both in igneous and metamorphic rocks, are imperfect. Its water percentage may be 1.5 or nil, and its molecular volume 227, 232 or 465. These figures point to a fairly high temperature and very low pressure as the condition conducive to its formation.

Staurolite in hand specimens has now been recorded from the following localities in the State: Mogumber and Greenbushes (S.W. Division), Mondooma, Mary River and Richenda River (Kim. Div.). In addition, microscopic grains have been observed in heavy sands from several localities in the South-Western Division, including Freshwater Bay, Cape Leeuwin, Pemberton and Cheyne's Bay.

* Based on a constant ratio for all four minerals of three Fe″ to one Mg. and on the assumption that the usual proportion of Fe‴ is negligible.

† Van Hise's data for prochlorite, on p. 196 of his Metamorphism, require revision. His molecular weight 1,382·52 seems to be based on two wrong assumptions, *viz.*, (1) that MgO is the only protoxide present, whereas as a matter of fact FeO and MgO are usually present in about equal molecular proportions, (2) that the empirical formula, copied from Tschermak, contains only two molecules, whereas it contains three of serpentine and seven of amesite, a total of ten. These molecules are not additive but substitutive. The true molecular weight is therefore in the vicinity of 318, varying with the relative ratios of Mg to Fe, and of Sp to At. His density 2·71 is too low, judging by the figures given by Dana; 2·85 appears to be a better figure for a unit ratio of Fe to Mg. Finally, his molecular volume, 509·216 is approximately five times too high, being dependent on the molecular weight and on the inverse of the density. Taking 318 for M.W. and 2·85 for density, the M.V. is 112.

Addendum.—Whilst the above was being written analyses of the clean staurolite and of the staurolite-bearing rock from Mogumber were in progress. These were subsequently completed with the following results:—

	Staurolite.	Staurolite Schist.
	%	%
SiO_2	29·12 ...	40·81
Al_2O_3	52·47 ...	30·69
Fe_2O_3	? ...	4·37
FeO	13·89 ...	5·86
MnO	·22 ...	·10
MgO	2·64 ...	5·52
CaO	·18 ...	·15
Na_2O	... ...	·88
K_2O	... ...	6·58
H_2O-	... ...	·09
H_2O+	1·46 ...	3·98
TiO_2	·82 ...	·90
P_2O_5	... ...	·08
S	... ...	*Nil*
	100·80	100·01
Sp. gr.... ...	3·76	2·91

Two kilograms of the rock were sampled down for the rock analysis, and a clean crystal free from inclusions and weighing 8.3 grams was taken for the mineral analysis. Neither Grubenmann, Zirkel nor Clarke gives any analysis of a staurolite schist with which to compare the figures for the Mogumber rock.

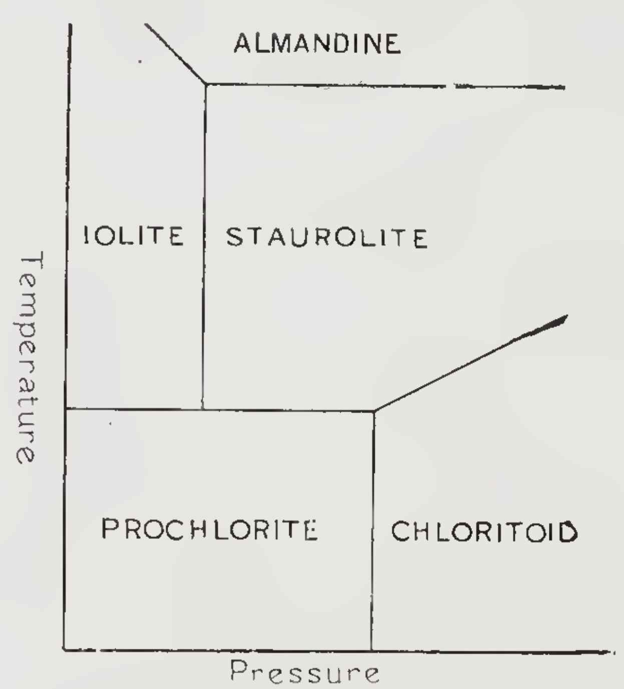

Plate X.—Diagram illustrating the physical conditions conducive to the formation of the Prochlorite Almandine Series.

PARASITISM OF THE QUANDONG (Fusanus acuminatus, R.Br.).

By D. A. Herbert, M.Sc., Economic Botanist and Pathologist, Analytical Department, Perth.

(*Read November 9th*, 1920.)

The Quandong (*Fusanus acuminatus, R. Br.*) is a native of Western Australia, and is variously known as Native Peach or Native Plum. It has a fruit somewhat bigger than that of the sandalwood, globular and red and about the size of a plum. This is edible and has a pleasant acid flavour. It is often made into jam. The quandong extends right down to the coast, a number of trees being found at Woodman's Point, south of Fremantle. Its wood is not valuable (though sometimes used to adulterate sandalwood consignments) and so it is as common in the bush as it ever was. It is closely related to the sandalwood and, like it, was found to be parasitic on surrounding trees. Cases of apparent isolation would at first sight appear to indicate that the quandong is not an obligatory parasite but on digging at isolated trees it was found that either a host plant had a long root running near the quandong, or else long roots of the quandong ran out and attacked distant roots. The haustoria are exactly of the sandalwood type. The investigation was carried out at Burracoppin in November, 1920, and the host plants found were *Acacia acuminata, Eucalyptus loxophleba*, and *Daviesia euphorbioides*.

Often the roots are parasitic on themselves. This is of no advantage to the plant but does no appreciable harm, though rather a waste of energy on the part of the plant. Most of these root parasites show self-parasitism: a property also shared by some stem parasites, such as *Cassytha* and *Cuscuta*.

OTHER SANTALACEOUS PARASITES.

Other parasites belonging to this family were found on investigation; in fact all the members of the family so far examined have been found to be parasitic. These results will be published in a future paper.

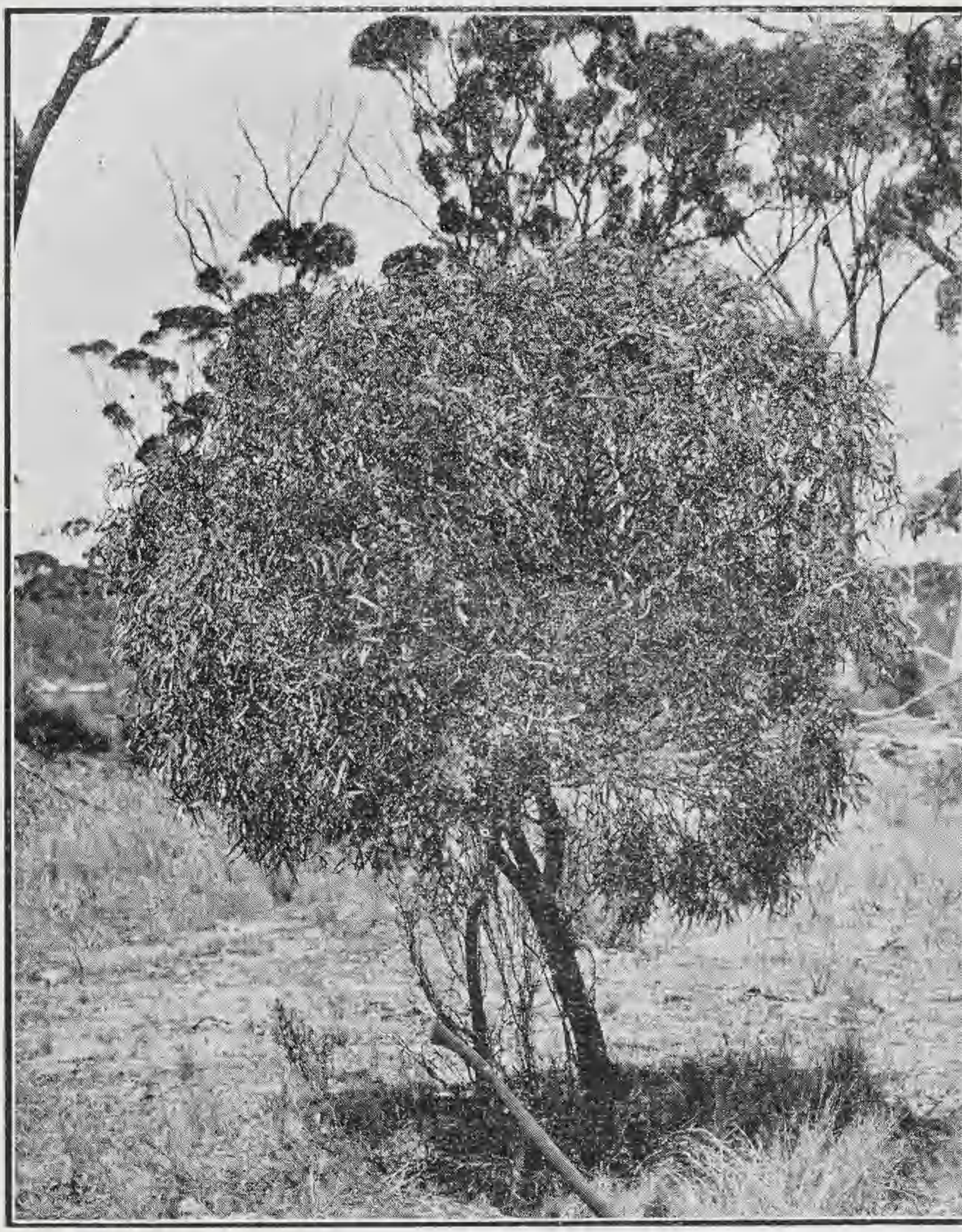

Plate XI.—Quandong.

PARASITISM OF THE SANDALWOOD (Fusanus spicatus, R.B.).

By D. A. Herbert, M.Sc., Economic Botanist and Pathologist, Analytical Department, Perth, and

C. A. Gardner, Forestry Department, Perth.

(*Read November 9th*, 1920.)

The Western Australian Sandalwood (*Fusanus spicatus*, R. Br.) is a low tree of about 20 feet, found throughout the drier areas of the State. It was once abundant, but now has been cut out for the greater part along the railway lines, and the larger trees are found only far back in the virgin bush. There is a big market for the wood in Asia, and in addition a certain amount of sandalwood is used for the distillation of the oil. For all practical purposes the Western Australian tree is an excellent substitute for the Indian tree, the wood of which was originally used. The Indian species is a tall tree known as *Santalum album*, and is well known to be parasitic. Rama Rao has found it in India parasitic on over one hundred different species of host plants. In this it rather resembles the Christmas tree of Western Australia, whose parasitism is not limited to one particular plant as is often the case with mistletoes and with fungal parasites. Other plants belonging to the Sandalwood family are well known to be parasites, and it was therefore to be expected that the Western Australian species, which is fairly closely related to the Indian tree, should also share this property. Its habit of growing close to another tree suggests this and it was not surprising to find that in such cases it was drawing on the other tree for nourishment. The favourite host plant seems to be the jam (*Acacia acuminata*), probably because it is the most common tree in districts examined. Numerous Myrtaceae, Leguminosae and other plants are also attacked. The sandalwood sends out branching roots, from which arise slender rootlets. These on coming into contact with the root of a jam tree form at the point of junction a club-shaped haustorium or sucker. This is different from the Christmas tree haustoriogen, which produces a ring of tissue round a host root with suckers on the inside of the ring.

The sandalwood roots rot easily in the ground, and it is not uncommon to find scars on the jam roots where a sucker has died, leaving its mark on the surviving jam roots.

When the attack is on an old tree there is generally little harm done, but when it is on a young tree it frequently kills it.

There is as yet no definite evidence that the sandalwood is an obligatory parasite, *i.e.*, that it *must* have a host plant in order to carry on its natural life functions, but this is probably the case. In India, Dr. Barber and Mr. Rama Rao have tried to raise sandalwoods without a host, but find that they die out as soon as the food materials are exhausted from the seed. They found it to attack an Australian plant, the Blue Gum of the Eastern States, which is cultivated there.

Raising Sandalwoods without the presence of a host plant at Pingelly proved a failure, but when the plantation was left to itself and other plants grew up, the sandalwoods flourished. This, therefore, seems to indicate that the plant is an obligatory parasite.

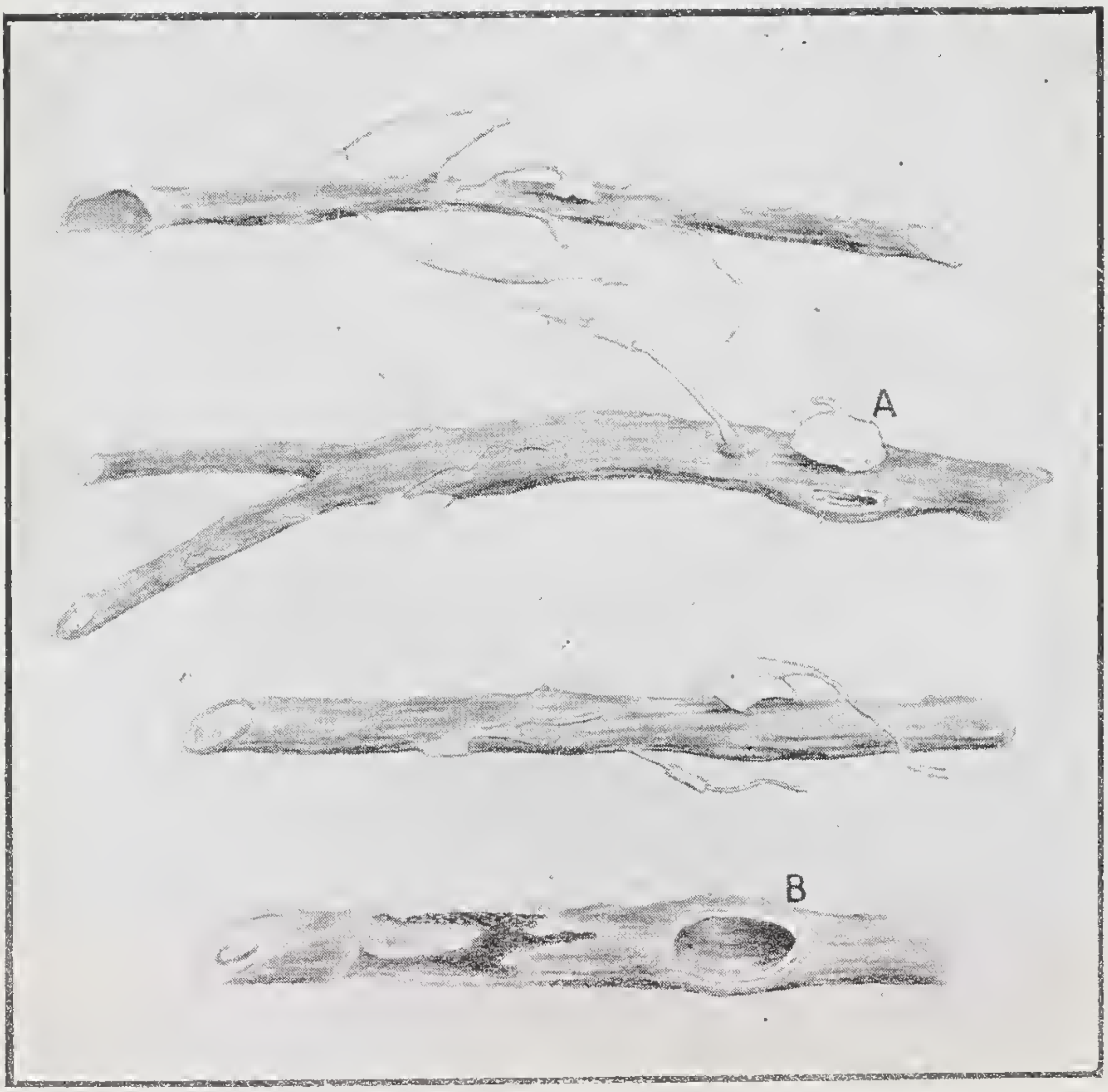

Plate XII.—Roots of *Acacia acuminata* attacked by haustoria.

THE GENUS XANTHORRHOEA IN WESTERN AUSTRALIA.

By D. A. HERBERT, M.Sc., Economic Botanist and Plant Pathologist, Analytical Department, Perth.

Read December 14th, 1920.

The genus Xanthorrhoea adds to the flora of South-Western Australia one of its most striking and decorative characteristics. The dominant species is *Xanthorrhoea Preissii,* the Blackboy, which though fairly distinct as a species, has such a wide range of distribution over widely different types of soils and through different conditions of moisture and rainfall that its different forms have produced a rather polymorphic species. These have resulted in the proposal of a number of species which on field examination are found to merge into one another or to be mere local variations of the ordinary type. Such are X. *pecoris,* F. v. M., and X. *Brunonis,* Endl. (Plantae Preissianae 11, 39). Another doubtful species is X. *Drummondii,* Harvey (Hooker's Kew Journal of Botany VII., 57) the description and account of which is as follows:—

Liliaceæ.

> *Xanthorrhoea Drummondi,* Harv.: trunco elato simplici, foliis rectangule tetraugonis, amento cylindrico longissimo (4—8) pedali), bracteis fasciculorum flore subbrevioribus apice barbatis, perigonii foliolis imberbibus.
>
> Hab. On dry hills, near Perth and elsewhere. This is the largest and finest of the genus, and produces the most valuable gum. It is readily known from the common Blackboy (*X. Preissii*) by the square, instead of rhomboidal section of its leaves, which are of a bluish green colour and far less brittle.

Harvey's type comes from the Swan River, and the main differences from *X. Preissii* are in field characters. It is probable that this species is identical with *X. reflexa,* D.A.H. (Proc. Roy. Soc. W.A. VI., part 1, 33) which, though typically an Avon species, also occurs scattered through the Swan River area amongst X. *Preissii.* The description, however, is too vague to make sure of this point.

X. *Preissii* probably attains its greatest dimensions on the coastal country from King George's Sound to the Leeuwin. Here specimens of 20 feet or more in height are of common occurrence, and the caudex may have as many as forty branches. One speci-

men at Nornalup has forty-five. This branching is characteristic of those plants growing in swampy localities, the blackboys of the dry hills and the sandplains having a simple or only slightly branched caudex. Branching frequently takes place below the surface of the soil, so that what at first sight appears to be a colony of distinct blackboys is really one plant arising from a common subterranean axis. In a typical specimen such as is met with round Perth on the laterite hills the stem is about nine feet in height, simple or with one or two branches, and about nine inches in diameter. On the coastal limestone belt amongst the tuart (*Eucalyptus gomphocephala*) the diameter may be much greater, up to 15 inches, though the height is not proportionally greater. Here, too, the persistent leaf bases consist partly of the linear portion of the leaf as well as the flattened part, and part of the increased diameter is due to this. There seems to be no other distinguishing feature of this form to distinguish it from the typical blackboy, but its general appearance is rather different.

Very frequently specimens are acaulescent or nearly so, and the absence of the caudex makes them appear more of the type of X. *brevistyla*, n. sp. Examination, however, shows no specific differences from X. *Preissii*. The extremely slow rate of growth of the blackboy accounts for this, and for periods of years no stem appears above ground. Along railway lines and in land which has been cleared for a long time and on which regrowth has taken place, these plants rarely attain a height of more than a foot or so. Specimens round Perth kept under observation for several years showed no appreciable change in height. Some of the giant specimens of the South-West must, therefore, be extremely ancient.

The caudex consists of two distinct zones, an inner core of fibrous leaf trace bundles, and an outer shell of persistent leaf bases impregnated with resin. The core contains a high percentage of sugar, and in the early days this was used in the preparation of whisky. The resin has been the subject of a great deal of investigation, and Rennie, Cooke & Finlayson * of Adelaide, have recently obtained from it—

(a.) A small quantity of fragrant liquid, not yet identified.

(b.) l-citronellol.

(c.) paeonol.

(d.) hydroxypaeonol.

(e.) a compound, which is possibly methoxydiphenyl ether.

(f.) a small quantity of a so far uncrystallizable material of very high boiling point.

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* Rennie, Cooke & Finlayson: An Investigation of the Resin from species of Xanthorrhoea. Journl. Chemical Society CXVII. (1920), 338.

Substances previously obtained by other workers were—

(a.) Acids, either free or partly in the form of esters—Benzoic, cinnamic, *o*-coumaric.

(b.) Aldehydes—vanillin, *p*-hydroxybenzaldehyde.

(c.) *Products of oxidation by alkaline Permanganate—Chromic Acid, etc.* Acetic and oxalic acids or insoluble chromium compounds.

(d.) *Products of fusion with Potassium Hydroxide*—Resorcinol, *p*-hydroxybenzoic acid, carbonic acid.

(e.) *Products of Action of Nitric Acid* Picric Acid, *p*-nitrophenol, acetic acid.

(f) *Products of Distillation with Zinc Dust in the Presence of Hydrogen*—Benzene, toluene, naphthalene.

(g.) *Products of Destructive Distillation*—Phenol, styrene and tarry matters.

(h.) A residue obtained by acidification of an alkaline solution, consisting of a complex substance, which has been named "resinotannol."

Rennie, Cooke, & Finlayson have examined the resin of *X. tateana*, F. v. M., a South Australian species. There are two forms of this. The resin of the common form is red, but that of a form from Kangaroo Island is yellow. Professor Osborne, of the University of Adelaide, who examined vegetative material of the latter, found it impossible to determine whether it was a distinct species or whether age or environment might not be the factors determining the differences from the normal form. It was found that paeonol occurred in larger quantities in the yellow than in the red.

The occurrence of the two resins in South Australia is of particular interest, as there are two forms of resin obtained from the species hitherto known as *X. Preissii*. The common form in the hills round Perth has a red resin, but a darker resin is obtained from a form which in a previous paper* was separated as a distinct species under the name *Xanthorrhoea reflexa.* No analyses of this have yet been published.

X. Preissii is a species typical of the Darling, Warren and Stirling Districts. *X. reflexa* is more typical of the Avon District, though it penetrates West amongst the other species in isolated patches. Its floral characters are not well marked from those of the previously described species, but its vegetative characters are very distinct. The reflexed leaf bases with their darker resin are an important point. The leaves are more square in section and tougher. The leaves in *X. Preissii* form a large globular tuft; in *X. reflexa*, they are more bluish and form a funnel shaped tuft at the top and

* D. A. Herbert; Proc. Roy. Soc., W.A., VI., part 1, 33, "Xanthorrhoea reflexa, a new species of Blackboy."

the old dead leaves hang down and form a mattlike petticoat round the upper part of the caudex. The dead and living leaves thus produce a sort of hour-glass shape instead of the more rounded bushy clump of the other species. Its stem is not so easily burnt and channelled by bush fires, though its leaf bases when broken up are more inflammable than those of the common blackboy. Another point is that in the pithy core a well developed woody cone is present in the base of *X. reflexa.* In *X. Preissii* this is not so evident, and may be absent. The former generally has a simple stem, sometimes attaining 15 or 16 feet, as at Popanyinning.

These two species are the only described arborescent ones in the South-West. It is possible (and probable) that there is a further species in the interior. Spencer Moore noticed it at Yilgarn, Giles at Queen Victoria Springs, and the Elder Exploring Expedition at Camp 55, in the Victoria Desert. Messrs. H. W. B. Talbot and E. de Courcy Clarke, of the Geological Survey, have seen them North of Wiluna and East of Laverton. They attain a height of about 15 feet. No specimens have yet been obtained, so that it remains to be seen if it is distinct from those already described from this or other States.

One stemless species has been described from the South-West. This is *X. gracilis,* a very common species with a slender, graceful scape and a small cylindrical spike of flowers. Two new species described below, approach acaulescence, but their short caudices often protrude a few inches above the ground. These are *X. brevistyla*, n.sp. and *X. nana*, n.sp. Both are closely related to *X. Preissii*, but are easily distinguished, the former by its short style, and the latter by the large capsule valves; other differences are contained in the descriptions. *X. brevistyla* might sometimes be taken for *X. gracilis*, for it frequently possesses the slender scape and very short spike of this plant, but generally its inflorescence is more like that of the common blackboy, though the flowering part is shorter.

XANTHORRHOEA BREVISTYLA, sp. nov.

Caudex—underground or very slightly protruding above ground, so that the plant is caespitose. It is frequently branched so that a number of leaf-clumps occur in a cluster.

Leaves—triangular in section, flattened, about three feet long and rather tough in comparison with *X. Preissii* and *X. reflexa.*

Base of leaves—flattened, not curved.

Scape—up to about six feet high, less than half occupied by the spike which is sometimes as short as in *X. gracilis.* Peduncle glaucous, slender, sometimes as much as in *X. gracilis.*

Bracts—narrow, linear, spathulate.

Bracteoles—narrow, linear, spathulate.

Perianth segments—inner four lines long and not one line broad, with a spreading hyaline apex; outer, shorter.

Stamens—6-7 lines long.

Ovary and style—shorter than the stamens, about four lines long, the style being three lines long.

Capsule—as in *X. Preissii.*

Locality—Narrogin. The type comes from the Narrogin State Farm, but the range is fairly wide as the plant, which has a very distinct appearance with its apparently caespitose tufts of leaves and often several erect scapes, can be observed as far south as Katanning along the railway line and for 20 miles or so west of Narrogin.

Date of collection—November 13th, 1920. (D.A.H.)

Its affinity is with *X. Preissii,* from which it is readily distinguished by the extremely short or absent caudex, relative length of the flowering portion as compared with the rest of the scape, and the length of the style.

XANTHORRHOEA NANA, sp. nov.

Caudex—very short, up to six inches high, and often branched.

Leaves—triangular or quadrangular and flattened in section, about two feet long and 2-3 lines broad, pungent and not so brittle as in *X. Preissii* or *X. reflexa.* They pass into a flattened base 1½ inches long.

Base of leaves—persistent, 3-6 lines broad, 1½ inches long, flattened but not curved.

Gum—yellow and not as abundant as in *X. Preissi* or *X. reflexa.*

Scape—about two feet long at first, horizontal, but curving upwards so that the flowering part is vertical or approximately so, and occupying one foot or less of the whole length. The scape is very brittle, snapping like a carrot when bent, and is conspicuously glaucous.

Bracts—narrow, spathulate.

Bracteoles—linear-spathulate, very narrow.

Perianth segments—inner slightly more than one line broad and five lines long or a little longer with a hyaline apex. Outer perianth segments shorter and with ciliate tips.

Stamens—6-7 lines long.

Ovary and style—7-8 lines long.

Capsule—1 inch long, valves ⅜ inch wide, with a point about ⅛ inch long.

Localities—Sandplain about two miles N.E. of Bruce Rock (type), and sand plain about 15 miles East of Merredin on the Burracoppin road.

Date collected—October 25th, 1920. (D.A.H.)

This species differs from *X. Preissii* and from *X. reflexa* in the height of the caudex, the tougher and shorter leaves, the leaf bases, the gum, and in the length of the capsule. In habit it bears little

resemblance to them though on close examination it is seen to have the same structure as the dwarfed scale. The settlers at Merredin do not regard it as a Blackboy, but know it as a Bulrush. On sand-plains, under cultivation, it is apt to be a nuisance as, after clearing, leaves are again produced from the subterranean part of the caudex.

Plate XIII.—Xanthorrhœa Reflexa.

PLEISTOCENE FOSSIL VERTEBRATES FROM THE FITZROY RIVER, WEST KIMBERLEY, W.A.

By L. GLAUERT, F.G.S., W.A. Museum, Perth.

(*Read 8th March*, 1921.*)

Through the good offices of Mr. Leslie Kingsmill, the Trustees have received an interesting collection of remains of Pleistocene Vertebrates obtained in the course of excavating a tank on Quambun Station, Fitzroy Crossing, about 170 miles by road from Derby.

Mr. E. S. Birch, the donor, states that the site of the tank is in a "slight depression covered with Bon timber (Coolibah), between fairly high sand hills that run S.W. by W." The first part of the excavation was in a stiff, dark slate-coloured clay five feet thick; this was followed by "conglomerate tightly cemented together," which varied in thickness and covered the lighter and softer bone-bearing clay.

As the work was done by ploughs, most of the bones are in a fragmentary condition, the only perfect ones being vertebrae and the bones of the manus and pes. In consequence of this and because of our lack of knowledge of the appendicular skeleton of extinct Macropods, etc., the number of specimens that can be identified with certainty is comparatively few.

It is interesting to be able to report the discovery of remains of an extinct Crocodile, though the presence of this reptile might be expected in the tropical part of W.A., as it is already known from Northern Queensland.

Macropus anak, Owen: An extinct kangaroo, has a very wide range, for it has been recorded from all the Australian States except Victoria. In Western Australia it has previously been obtained in the Mammoth Cave, near Cape Leeuwin and Balladonia.

Crocodilus sp.

The identified specimens consist of two teeth and a nuchal scute.

Phascolonus gigas, Owen.

Fragments of a right upper incisor and a left lower incisor, pieces of ribs, and an imperfect atlas vertebra represent this species in the collection.

* By permission of the Trustees of the Museum.

Macropus anak, Owen.

A fragmentary maxilla bearing the molars M^2 and M^3, and a right lower incisor have been identified as belonging to this species.

De Vis found that in Queensland the bones associated with the teeth of *Macropus anak* indicated an animal much more massive than a living kangaroo of similar size; in view of this a number of bones of Macropine type, but short and heavy, are provisionally ascribed to this species. They consist of cervical, dorsal, lumbar, and caudal vertebrae, a fragmentary scapula, the distal half of a humerus, and fragments of the femur, tibia, fibula, as well as numerous more or less perfect bones of the pes.

CONTRIBUTIONS TO THE FLORA OF WESTERN AUSTRALIA, No. 3.

D. A. Herbert, M.Sc., Economic Botanist and Plant Pathologist, Analytical Department, Perth.

(*Read 13th June*, 1921.)

CASUARINEÆ.

Casuarina horrida, sp. nov.

A shrub of about nine feet in height with numerous erect, rigid branchlets. Whorls mostly 10—12 merous, the teeth short, dark, the internodes obscurely striate. Male amenta not seen. Cones rather small, depressed, globular, half an inch in diameter. Bracts villous on the outside, very short, less than one line long, broad, cuneate, mucronate, about half as long as the valves. Valves nearly two lines long, villous except the upper third, which is dark, the dorsal protuberance attached about one-third of the way from the base, villous, the broad part shorter than the valve, produced into a fine curved glabrous spine of two lines which gives the cone a bristly appearance. Achene brownish-black, produced at the apex into an oblique membranous wing.

Locality: Merredin, on sand plain. Also observed, but not collected, at Westonia, in similar country.

Collectors: Herbert & Wilson, No. 99.

Date: November, 1920.

Following the arrangement adopted in Bentham's *Flora Australiensis*, this species falls into the section *Acanthopitys*, and has its closest relatives in *C. thuyoides*, Mig., on the one hand and in *C. bicuspidata*, Benth., on the other. It resembles the former in the number of teeth in the whorls, and the latter in the cones, the points of the dorsal protuberances, however, being much finer. Male spikes are necessary to complete the description. The name is in allusion to the bristly appearance of the cones. The type is in the Western Australian Government Herbarium, specimens collected at the same time being in the Arnold Arboretum at the Harvard University.

MYRTACEAE.

Thryptomene fimbriata, sp. nov.

A globular compact shrub of about 18 inches in height with slender virgate branches. Leaves erect or spreading, linear, semi-terete, obtuse, about one line long, 10 ribbed; lobes fringed, quarter line or less in length. Petals three-quarter line long, not quite as broad as long. Stamens 10; anther-cells about twice as long as broad, distinct, dehiscing by slits, the connective thick. Ovules 4, on a short lateral placenta.

Locality: Dowerin, in yellow sandy soil in mallee thickets.

Collector: C. A. Gardner.

Date: August, 1920.

The new species is so named on account of its fringed calyx lobes which readily distinguish it from the other species. Its nearest affinity is with *T. australis*, Endl., from which it differs in the length of the leaves, absence of the short fine recurved point (rarely wanting in *T. australis*), the cylindrical calyx tube, and the shorter and fringed calyx lobes. One of the localities for *T. australis* given by Bentham is East of New York (Roe). This locality obviously should be East of York.

PROTEACEAE.

Persoonia angustiflora, Benth., var. *Burracoppinensis*, var. nov.

An erect shrub over one foot in height; leaves mostly under one and a half inches; flowers solitary; anthers with short points or appendages (about a quarter line long) to the connective.

Collectors: Herbert & Wilson, No. 100.

Locality: Burracoppin.

Date: November, 1920.

Similar in the leaf to *P. rudis*, and bearing a superficial resemblance to that species, but lacking the spreading hairs. It is easily distinguished from that species by the glabrous style.

SOLANACEAE.

Solanum dioicum, W. V. Fitzgerald ms. & herb. (Syn. *Solanum Cunninghamii*, W.V.F., non Benth.)

This species is described in Mr. Fitzgerald's paper on The Botany of the Kimberleys, North-West Australia (Proc. Roy. Soc., W.A. III. (1917), 203) under the name of *S. Cunninghamii*, Benth. This is an error. In the original manuscript the same description is given for *S. dioicum*, W.V.F., and applies to Fitzgerald's specimens labelled *S. dioicum*. *Solanum Cunninghamii* is readily distinguished by the inflorescence.

ORCHIDEÆ.

Corysanthes pruinosa, A. Cunn.

(Big Brook, June, 1921, per W. C. Grasby.)

This orchid was growing in the trunk of a blackboy. It was previously recorded from the Stirling district in Bentham's *Flora Australiensis* under the name of *C. fimbriata*, R. Br. This new locality is in the Warren District.

FUNGI.

Uredo angiosperma, Thuem.

The host plant for this is *Hakea glabella*.

Puccinia helianthii, Schw.

Sunflower rust, on *Helianthus annuus*, Subiaco, January, 1921. (D.A.H.).

ON A NEW SPECIES OF NAIDIFORM WORM,

Dero roseola.

By G. E. Nicholls, D.Sc., F.L.S.,

Professor of Biology in the University of Western Australia.

When engaged, recently, in examining a number of samples of muddy water in search of protozoa for class purposes, I came upon several specimens of a very slender and elegant naidiform worm.

In view of Michaelsen's statement (1907, p. 118) that in the south-western portion of Australia, the fluviatile Oligochæta are very rare, my attention was at once arrested by the discovery. The particular sample of water was one taken from a horse-trough in South Perth. This trough proved, upon inquiry, to be fed by an inlet pipe connected with a deep bore (1,800 feet), the water from which is highly mineralised* and has, at the surface, a temperature of 103° F.

Further samples of the sediment from the bottom of the trough were taken and showed the worms present in great numbers, several hundred being obtained in a single dip of a large test tube. Associated with them were an unidentified *Chaetogaster*, and many *Chironomus* larvæ, while the surface of the sediment was crowded with a large Ostracod and abundant *Cyclops*, the latter heavily infested with an *Epistylis.*

On allowing the mud to settle, the worms were found to collect in dense aggregations against the side of the vessel (Fig. 1), forming conspicuous pink masses. The anterior end of most was thrust downwards into the sediment, while the greater part of their length swung up more or less vertically with continuous swaying movement.

Nearly transparent, the worm (Fig. 2) appears by transmitted light of a delicate pink colour, due to the contained blood, and at once recalled the beautiful *Dero furcata* which I, at first, supposed it to be. It has at its posterior end a pair of ventrally situated, elongate cylindrical palpi, which are extremely mobile. Lateral and dorsal to these are three pairs of well developed branchiæ, richly ciliated (Figs. 4, 5). Together these structures form a fringe to the funnel-shaped chamber into which the intestine widens at its posterior end. All are contractile, the branchiæ especially so, and in preserved specimens they usually appear only as short thick knobs inturned and almost withdrawn into the anal chamber (Fig. 4). Two of these branchial processes on either side are of practically equal length, but the most anteriorly situated pair, springing from the dorso-lateral surface of the anal funnel, are somewhat shorter. In

* Analysis of the water reveals 96 parts solid per 10,000.

the living specimen a well marked insetting current of water is produced by the action of the cilia of the intestinal epithelium.

Like *Dero furcata*, too (and differing from all the other species of the genus), it shows the cephalisation restricted to the three segments behind the peristomial (Fig. 3). That is, there are present ventral setæ only upon segments 2, 3, and 4; dorsal setæ occur in the 5th and following segments.

My specimens differ, however, from *Dero furcata* as described by Bousfield (1886. p. 105), in a number of particulars. The number of segments most frequently found is 75, the worm having a length of about 12 mm. (10 mm. in the preserved state). It is in worms of that length that what I take for incipient budding is to be looked for, the 28th segment occasionally showing indications of what appears to be the formation of new small segments devoid of setæ (Fig. 2). Other than this, budding has not been observed, although many specimens with a smaller number of segments have been seen. In these latter, the branchial apparatus is usually less perfect and they are probably immature forms resulting from asexual reproduction.

In its habits the worm, under laboratory conditions, resembles rather the free *Dero* (*Aulophorus*) *vaga* of Leidy's descriptions. It moves rapidly through the water by an undulating movement, or it may crawl more slowly upon the side of the vessel by means of its setæ. Numbers of them will take up their abode within decaying grass stems or in the interior of short lengths of straw, while I have seen them, not infrequently, as temporary tenants of the much too large tubes of Chironomus larvæ. One specimen only has been found (within a short length of straw) in its proper tube, a delicate transparent structure to which many small mud particles were adherent.

The structure and arrangement of the setæ depart but little from that which seems to characterise the other species of *Dero*. The setæ in the first ventral bundle (segment 2) are normally but three in number. In the succeeding segments there seem to be four invariably. Contrary, however, to what is stated by Bousfield of *Dero* in general (*op. cit.*, p. 98), the length of these setæ does not considerably exceed that of the corresponding structures in the later segments. On the contrary they appear to increase slightly in length in successive segments until segment 8 is reached. All the ventral setæ appear to be of the hooked (acicular) type.

Of the dorsal setæ there are but two in each bundle. The single capillate seta never reaches a length approaching that of the diameter of the body, while the short sigmoid seta accompanying it has relatively, a considerable length, projecting quite visibly well beyond the skin.

Two or three segments at the posterior end of the body are devoid of dorsal seta bundles, but the ventral setæ are missing from the last segment only.

Under the microscope the worm maintains a restless movement. Even when its movements are impeded by a mesh of cotton wool it is never still, and it is a matter of much difficulty to make out its internal structure. Under such conditions, moreover, the branchial apparatus is greatly retracted. I am able, therefore, at the present time, to state but little concerning its anatomy. The number of "contractile loops" could not be certainly determined, but seemed not to exceed two pairs; while a gastric enlargement, as distinct from a succeeding intestine, was likewise not to be readily distinguished. Nor could I certainly recognise reproductive organs, although these might have been expected to have been developed, since my specimens were taken at the end of the summer season and, as already noted, budding did not appear to be taking place at all freely. It is of course possible that the modification of the body in the region of segments 27-29 is not evidence of incipient budding but may represent a clitellar thickening, though such a position for the clitellum would seem to be unusually far back. In Bourne's figures ('91) the budding region has setæ developed from the first cutting-off of the new segments apparently, whereas in my specimens setæ seemed missing here. It is to be remarked that this thickened region was seen in relatively few specimens, all presumably mature, since they possessed what is apparently the maximum number of segments, viz. 75.

The terminal "palpi" are not, in this species, markedly longer than the branchiae, whereas in *D. furcata*, as figured by Bousfield (*op. cit.*, figure 18), the palpi are shown more than twice as long as the branchiae.

Bousfield stated, as his opinion, that Leidy's species *Aulophorus vagus* is identical with the *Dero furcata* of Oken, differing merely in that the worm found by Leidy was free. I have been unable to refer to Leidy's work, but find that Pratt, in a "Manual of Common Invertebrate Animals" ('16), reproduces a figure by Walton ('06) of *D. vaga* Leidy, which figure suggests a much shorter, stouter worm than *D. furcata*. In this manual *D. vaga* is said to consist of 25 to 35 segments. Bousfield defines *D. furcata* as possessing 35 segments and as tube-inhabiting. The Western Australian form has 75 segments, and has been found but once in a tube. All three agree, however, in a cephalisation differing from the remaining species of *Dero*, in that in the latter the dorsal setæ begin in the sixth segment, whereas in these three species the most anterior dorsal setæ are found in the fifth segment. All of these three species, too, are peculiar in the possession of paired terminal palpi.

Bourne (*op. cit.*) remarked upon this anomalous cephalisation in *D. furcata* (to which Bousfield had directed attention) and stated that, in his opinion, the character was one of sufficient importance

to warrant the establishment of a new genus for *D. furcata*. Bourne, however, had not apparently actually seen examples of this species and refrained from proposing a new generic name. It would seem that these three species are really quite distinct from the remaining members of the genus and might well be separated generically.

Dero roseola, n. sp. (Pl. XIV., Figs. 1-5.)

Segments, 75. Branchial area funnel-shaped, bearing a pair of mobile cylindrical palpi and three pairs of ciliated branchiæ, cylindrical in shape and almost of equal length but slightly shorter than the palpi. The first pair of dorsal setae bundles occur in segment five. The first ventral pair of setæ bundles in segment two consist of but three setæ apiece. Succeeding ventral bundles have each four setæ. The worm is of a delicate pink colour, reaches a length of 12 mm., and is rarely found inhabiting a tube, but may be found collected into dense clusters forming a distinct pink mass.

Literature cited:—

'91. Bourne, "Notes on Naidiform Oligochætæ," vol. 32, Quart. Journ. Micr. Sc., 1891.

'86. Bousfield, "The Natural History of the Genus *Dero*," vol. 20, Journ. Linn. Soc. Zoology. Lond., 1890.

'80. Leidy, " , American Naturalist, 1880.

'07. Michaelsen, "Oligochaeta," Die Fauna Südwest-Australiens, Bd. 1, Lief. 2. Jena, 1907.

'16. Pratt, "A manual of the Common Invertebrate Animals." Chicago, 1916.

'06. Walton, "Naididæ of Cedar Point," Amer. Natur,. vol. 49, 1906.

Description of Plate:—

Fig. 1. A part of a cluster of living *D. roseola*, as seen under the binocular microscope, x 12.

Fig. 2. An entire worm, killed and somewhat contracted, mounted in glycerine, x 25.

Fig. 3. Anterior end of the same specimen, showing prostomium and eight segments more highly magnified, x 100.

Fig. 4. Dorsal view of posterior end of another specimen, showing the branchiæ almost entirely retracted within the anal funnel, x 100.

Fig. 5. Ventral view of the posterior end of a third specimen, the retracted branchiæ visible through the transparent ventral wall of the anal funnel, x 100.

Figs 2-5 drawn with the aid of a Zeiss drawing camera.

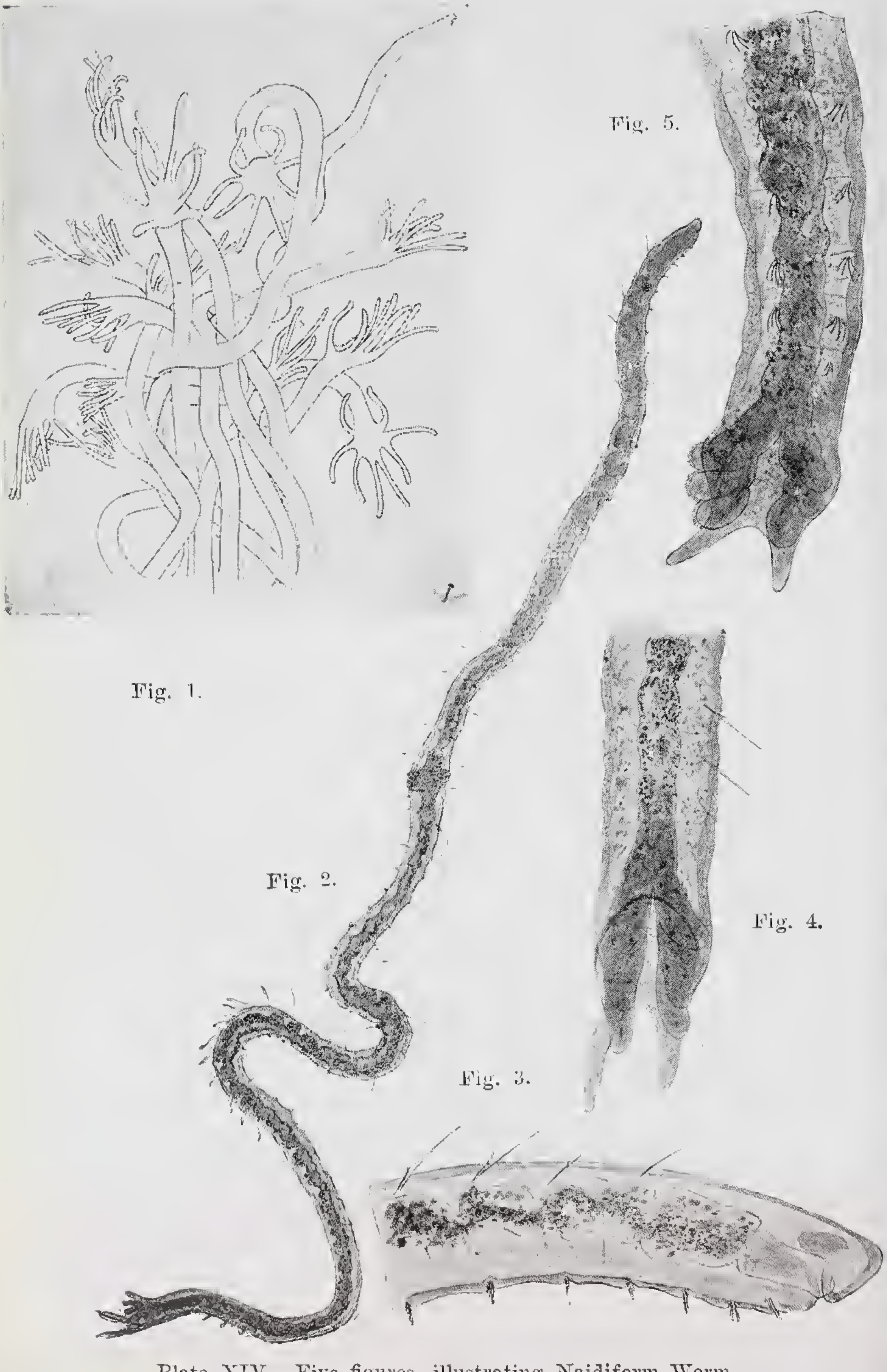

Plate XIV.—Five figures, illustrating Naidiform Worm.

XEROPHYTISM IN THE SWAN RIVER DISTRICT.

By W. E. Shelton, B.Sc.

(*Read on* 13*th June,* 1921.)

The term xerophyte is applied to plants capable of thriving in an environment unable to provide a normal plant with a sufficiency of suitable water. Such plants may be found in quite widely differing regions. Hot deserts, arctic, antarctic and alpine lands, acid swamps, beach or salt-lake areas, all offer plants very limited supply of suitable water during the whole or a large part of the year. The ice-bound portions of the earth have no liquid water available for plants, while beaches, salt-lakes and swamps usually provide only water charged with injurious substances.

The Western Australian bush is crowded with xerophytes. Our rainy season plants must not be included, however, for they either pass through the whole of their lives in the months of rain or else lie dormant underground as bulbs, corms, rhizomes or tubers during the season in which their aerial portions are unable to withstand the hot drying influence of our summer sun.

The xerophytic vegetation is of another type. It provides the permanent flora and comprises those plants which are able to withstand the whole round of the seasons for perhaps many years. In our ten, nine, and even eight inch rainfall belts, dense assemblages of plants are found, here and there rising to the dignity of forests, and the plants so met are all able to flourish throughout the months of the year in which the precarious replenishment of water supply is dependent on occasional thunder showers. Even the poorly retentive sandy soils carry their cloaks of vegetation.

The secret of this continued existence in such a forbidding environment is revealed by a study of the morphology and anatomy of the plants. Numerous departures from normal structure are to be noted and these are concerned with (a) absorption, (b) storage, and (c) loss of water.

With regard to absorption, the root system is usually highly developed. Sometimes it is the great depths of the soil which are searched for water, while often an up-rooted gum tree shows an extended surface network of roots, eminently fitted to absorb rapidly the moisture from short summer storms. In addition, curiously modified hairs, capable of absorbing dew deposited on the plant surfaces, are occasionally to be seen.

Water storage tissues are to be found in all parts of plants. Bulbous roots such as those of Droseras, swollen stems of some salt-bushes[1] and fleshy leaves of the "pig-face,"[2] all furnish

1. Salicornia Australis. 2. Mesembryanthemum Aequilaterale.

examples. In many of our xerophytes, too, the epidermal cells are of considerable size and contain an appreciable reserve of water. This is particularly noticeable in the "ice plant."[3]

Chief plant activity, however, has been directed towards minimising transpiration. Loss of water is a source of grave danger to most of our bush plants. If the rate of such loss exceeds that at which absorption proceeds, the plant is forced to draw on its water reserves. Should these become depleted, growing tips of roots and shoots lose power of growth, drooping commences and still further desiccation results in permanent injury or death. But transpiration is a necessary danger. In plant nutrition, constructive metabolism demands at least seven soil constituents. These can be obtained only in solution by the absorptive system of the plant. The continuous supply of these soil constituents is dependent, then, on the steady inflow of soil water. Since the water-holding capacity of any plant is limited, it follows that the uninterrupted entry of dissolved minerals is dependent on provision being made for the escape of water from the plant surface. Water loss, therefore, is necessary. In humid climates, where evaporation is exceedingly slow, certain plants (Tropaeolum majus and Fuchsia) exhibit structural modifications which allow the exudation of water from definitely placed pores. In our dry season, however, hot dry air, renewed by almost constant winds, accelerates the rate of evaporation to such an extent that even the hardiest of our introduced garden plants needs the constant care and protection of the gardener.

Normally, transpiration is not permitted to take place over the whole area of the plant. A waterproof cuticle restricts it to the stomata on the green portions, and in the corky regions lenticels are provided. To the lenticels of our plants I have paid but little attention. They certainly are not prominent features and probably are poorly developed. Moreover, it is to the neighbourhood of green surfaces that the transpiration current brings the materials required in the metabolism following on photosynthetic activity. Stomata are most numerous on leaf surfaces and therefore it is to the leaves of xerophytes that we look for the chief evidences of modification.

I have selected at random the leaves of a few of our plants, and a study of stained sections shows how their anatomy specially enables them to guard against excessive loss of water vapour.

1. Banksia attenuata.

Plate XV., Fig. 1, shows the typically bifacial structure exhibited by a transverse section of a leaf of this plant. Stomata

3. M. Crystallinum.

are restricted to the shaded underside, and there, free circulation of air is prevented by a dense layer of short, curly hairs. These are present in such numbers as to give the lower surface of the leaf a white colour. Another xerophytic structure is the layer of mechanical fibres underlying the upper epidermis. These fibres remove the softer mesophyll tissues from the dry atmosphere and give a noticeably hard texture to the whole leaf.

The reduction of the softer tissues from which evaporation is liable to take place is characteristic of xerophytic plants. Their replacement by sclerenchyma renders the vegetation harsh and gives a profusion of spines, prickles and thorns.

Dryandra Floribunda.

Plate XV., Fig. 2, shows a transverse section of a leaf of this plant. On the under surface of each leaf there are numerous pores leading into spacious flask-like cavities hollowed out in the spongy parenchyma. Stomata are restricted to the inner surfaces of these cavities. The remaining external surfaces are protected by a thick waterproof cuticle. As a result, the stomata are not exposed directly to the sun's rays and the air on to which they open is changed exceedingly slowly and soon becomes almost saturated with water vapour. Evaporation through the stomata, therefore, is greatly retarded. The efficiency of the system is still further enhanced by numerous hairs which arise from the epidermal cells lining each cavity and which produce a plugging effect at the pore-like opening.

The mechanical tissues of the leaf are strongly developed, a layer of sclerenchymatous fibres underlying the epidermis, increasing the distance between the softer tissues of the mesophyll and the leaf surface. This lessens the tendency for evaporation to occur, tempers the brightness of the sunlight and at the same time makes the leaves so hard that they feel like thin chips of wood.

A slightly contradictory feature is the lens-like appearance of the epidermal cells overlying the groups of palisade cells. It would seem that they function in concentrating the light on the assimilation tissue beneath, but probably they serve chiefly as water reservoirs close to the regions of greatest photosynthetic activity.

Ammophila Arundinaceae.

The next xerophyte to be mentioned is *Ammophila arundinacea*, Host (the Marram Grass), examples of which may be found growing close to the beach near Perth. Although not an indigenous plant, it is so well established as a naturalised alien that it is not out of place to mention it here. This grass I first gathered with other plants at the Osborne Rifle Range. On examining the long

linear leaves later, I was surprised to find them tightly rolled into the form of a straw, tapering to a point. Transverse sections of the leaves appeared as shown in Fig. A of Plate XVI.

On the upper surface of the leaf are pronounced flattened ridges separated by furrows. A smaller more wedge-shaped ridge divides each main furrow into two secondary furrows. The section shows that the ridges are due to girders of sclerenchyma, one being formed along each vascular bundle. The vascular bundle exactly resembles that of maize. The mesophyll consists of a compact parenchyma, slightly differentiated into columnar cells on the lower (outer) surface. Intercellular spaces are practically wanting. A small air cavity exists behind each stoma, but no other spaces are seen in a transverse section. There is therefore little cell surface exposed to an internal atmosphere and, consequently, evaporation is limited. On the other hand, no cell is more than three or at most four cells removed from the air cavity of a stoma and so can obtain by diffusion any carbon dioxide required for photosynthesis. The epidermis of the outer surface has a strongly developed cuticle and the lens-like enlargement of epidermal cells for light concentration and water storage is well shown.

Chief interest, however, is centred about the abnormal epidermis of the inner surface of the leaf. On the summits of the girder-like ridges the epidermal cells are small, frequently conical, or else produced into stout conical hairs. In the secondary furrows the epidermal cells are enlarged into thin-walled sacs, often conical, containing large water reserves and with bases in close contact with the compact mesophyll. Cuticle is but slightly developed in the furrows.

On excessive transpiration causing an undue loss of water, the enlarged epidermal cells (which we can call the "Curvature Tissue") in the furrows become less turgid, and shrinking, diminish the length of the epidermis stretching across the furrows. The width of the whole epidermis of the upper side of the leaf is diminished. At the same time the compact photosynthetic mesophyll contracts, water loss causing shrinkage of cells not separated by air spaces. Since the outer epidermis, protected and strengthened by its tough cuticle does not similarly alter in dimension, a curving takes place, each furrow and the whole of the inner surface of the leaf becoming more concave. Should the water deficiency continue to increase the furrows are obliterated gradually by the approach of the side walls and the whole leaf is tightly rolled. In plucked leaves this change takes place with great rapidity, curvature being marked in five minutes. This indicates that in the expanded position of the leaf transpiration is rapid, the plant by leaf movement being adapted to either dry or wet conditions. It is a plant well fitted for life in our climate of

seasonal extremes. Fig. A of Plate XVI. shows a leaf partially curved, while Fig. B is a more highly magnified view of the curvature tissue lining a secondary furrow.

The closing of the furrows (into which the stomata open) prevents circulation of air in the pit-like entrances to the stomata, and this end is further served by the interlocking of the stout hairs which grow in greatest profusion at the edges of the longitudinal ridges. Finally, on rolling being completed, the furrows themselves open on the closed cavity contained by the rolled leaf. There is then a most striking and successful attempt to protect the plant from excessive transpiration.

On the checked transpiration allowing the plant to make good by absorption the undue water loss, the cells of the curvature tissue and the green mesophyll regain their turgor and the leaf unrolls.

Reference to the structure exhibited by an oat leaf is informative with regard to the origin of the specialised structures of the marram grass leaf.

Leaf of Xanthorrhoea preissii.

The long brittle, prismatic leaf of this plant is anatomically divided into two distinct zones.

The outer layer, shown as a narrow border in a transverse section (Plate XVII.) contains the chlorophyll-bearing cells and much sclerenchyma. This latter tissue forms girders, triangular in section, running in the direction of the length of the leaf, the broad bases forming a rigid support for the epidermis. The outermost layer of sclerenchyma, one cell thick, is marked off from the remaining portion of this tissue by taking acid fuchsin stain more feebly, and consequently stands out as a light line between the epidermal layer and the cells situated more deeply. It also runs continuously, forming a connecting link between neighbouring girders of sclerenchyma. The chlorophyll-bearing cells form columns of palisade tissue lying between the sclerenchyma strands, and are crowded with polygonal chloroplastids. In the transverse section, the palisade tissue appears as a series of scallops around the margin of the leaf, each portion of it being so placed with respect to the sclerenchyma that the light is much tempered. The epidermis is composed of conical cells, the cavities being much encroached upon by thickenings of the cell walls. A cuticle is strongly developed. The stomata are well protected by clusters of blunt hair-like outgrowths of the epidermis. Another distinctive feature is the lining of the stomatal cavity by a continuation of the outer layer of sclerenchyma mentioned above. In this region, however, many of the fibres are irregularly formed and fissures

appear between them. An interchange of gases between the external air and the palisade cells is therefore permitted, but to a restricted extent. In addition, the palisade cells fit compactly together, so the loss of water vapour must of necessity be slow.

The inner region of the leaf contains large parenchymatous water-storing cells, but loss of water to the outer border is restricted by the interposition of a row of mechanical fibres. The portion of the section within these fibres has a structure somewhat similar to that of a monocotyledonous stem. Vascular bundles appear throughout the section. On examination it is seen that they are not scattered indiscriminately, but appear in more or less definite lines seen running laterally across Fig. A of Plate XVII. As in Zea mais, each bundle is enclosed in a sheath of mechanical tissue. Within this are two distinct sets of xylem cells forming a "V" and almost meeting at the apex which is directed towards the central parts of the leaf. The outer ends of the xylem sets enclose the phloem, which is cleft in two by a median strand of sclerenchyma. The bundles nearest the leaf surface are imperfectly formed, being in fact the ends of vascular strands which occupy a more central position in a section at a lower level of the leaf. Two such bundles are shown in Fig. B, Plate XVII., and in them the xylem sets are not well marked. Each bundle is so oriented that the phloem is directed towards the nearest surface of the leaf.

The chief xerophytic characters shown in the leaf structure of the Blackboy are:—

(1) Water-storage tissues in central portions of leaf.

(2) Prevention of excessive transpiration by—

(a) limiting of stomata to strips of leaf surface overlying the palisade cells;

(b) a thick cuticle;

(c) removal of delicate parenchymatous cells from epidermal layer by the interposition of much sclerenchymatous tissue;

(d) Minimising water loss through stomata by blunt hairs, narrow entrances, and an almost continuous layer of woody fibres which separates the stomatal cavity from the parenchymatous cells below.

(3) The water distributing xylem elements of the vascular bundles are strongly developed.

Each leaf examined shows some adaptation for water conservation. and though in many leaves the structural features are very similar, it happens that now and again some rarer device is displayed. The origin of these features to which the plants owe

their continued existence affords ground for most interesting speculation and is intimately connected with the history of our portion of the Australian continent.

The land surface of south-west Australia is an old one, having maintained its position during earth changes which have caused other land masses to be raised above or submerged below the ocean waters. In addition, through a very great period of time, there has been a continued isolation from other land regions. As a result, our flora (and fauna also) has in large measure been able to maintain a certain air of primitiveness. Associations of she-oaks,[4] blackboys,[5] banksias,[6] seem to afford us glimpses of the vegetation which has long since passed away from other portions of the earth. (On the other hand it has to be borne in mind that others of our plants—lilies, orchids, compositeae, etc., show the same structural development met with in other continents, but these are annuals or have no aerial portions during the dry season. In fact, although not xerophytes, their life histories are perfectly adapted to their climatic environment.) But, undisturbed by alien plant invasion, the local flora has been subject to disturbing attacks of quite another nature. The great antiquity of our land has enabled it to experience profound climatic changes. Even north in the tropics we find the records of past glacial activity, but the change which has done most to determine the present type of our flora has been a prolonged period of slow desiccation. Physiographical evidence indicates that the major portion of our wheat belts, now dependent for summer water on artificial storage of the winter rains, once formed portion of the well watered valleys of a huge drainage system, the main river of which was a mighty stream, estimated by some to have risen in the Murchison region and to have entered the sea at a coast line approximating to our present-day south coast. It is probable that the old river levels assisted largely in the grading of the Great Southern Railway. Apart from this, weakly streams such as the Chapman River have a flow of water quite incommensurate with their large rock-cut valleys, while other ancient river valleys are shown only by exposure of fluviatile deposits such as those in the railway cutting near Mullalyup. Physiographic evidence also shows that at least on two and perhaps on three occasions, after large land uplifts, drainage systems were able to reduce the land surface to a peneplain at sea level.

The deduction following these facts is that at some remote time, the flora of a large part of Western Australia must have been in equilibrium with climatic conditions largely determined by a plentiful water supply. Such mesophytic and hygrophylous

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4. Casuarina Fraseriana. 5. Xanthorrhœa Preissii or X. Reflexa. 6. Commonly Banksia Menziesii.

plants must have included the ancestors of the present day species, and probably also other types, the descendants of which have become extinct. Fossils from portions of our inland South-West and Great Southern areas have proved to be remains of Laurineae—cinnamon-like plants—which almost certainly lived in a moist tropical or sub-tropical climate. Horizons of coal measures, partly lost by denudation, are being exposed over increasing areas, and these, too, furnish some evidence of ancient floras and environments.

On the living materials (probably the chromosomes in particular) of the ancestors of our xerophytic plants, drying climatic conditions exerted a new set of stimuli. The development of certain characteristics met with repression whilst others, so checked by the old order of conditions that they were not able to be evidenced at all, slowly made their appearance owing to either the stimulation or lack of repression of the new external environmental factors.

In some instances, doubtless, the changes induced in the plants were not beneficial. The resultant state of a plant so modified would leave it to adjust itself to changing conditions with no means for so doing. In other cases, the changes may have been inimical, with the result that necessary functions could be carried on but imperfectly. Whichever the case, changes being inimical or merely immaterial, the effect would be evidenced in a retarded rate of reproduction, natural selection ultimately leading to extinction of the plant in regions of appreciable environmental change.

It is certain that in the cases of at least some of the ancestors of our xerophytic plants, beneficial alteration of characteristics followed modification of environment. Bufon, advancing the idea of variation of species, and Erasmus Darwin, of the inheritance of acquired characters, first led modern thought towards the great truth of progressive evolution. In the light of this truth, we may believe that here in this State, through very many hundreds of generations, progressive change of structure followed the gradually changing water relationship. Such progressive modification, established in the cases of many organisms, is capable of effecting quite drastic structural alteration within that portion of geological time to which fossils give us reference, and such change is almost certainly responsible for much of the specialised anatomy and morphology of our xerophytes.

Some of the plants actually indicate in the individual the progressive development of their race. The first leaves of seedlings, differing from those of the mature plant, probably resemble the ordinary foliage leaves of remote ancestors. In the case of wattle seedlings, it may be noticed that the first leaves are bipinnate, like

those of a typical acacia. Those formed next show some reduction in the surface area of the small leaflets, while a compensating expansion of the leaf stalk enables photosynthetic activity to be maintained. Lastly, foliar growths consist of expanded leaf-stalks only, no trace of the acacia-like leaflets being displayed. We here see each individual climbing its genealogical tree, showing clearly a progressive reduction of leaf surface, which must have accompanied the growing aridity of environment.

It seems, then, that external factors are able to affect the body tissues. These, in their turn, must influence the metabolism of germ plasm and so cause variation from generation to generation.

A Darwinian progressive variation such as that suggested above does not exhaust possible explanation of the origin of xerophytic structures. Change of external conditions, or wide interspecific crossings, may cause changes in number, function or chemical composition of chromosomes or more general changes in the protoplasm of a cell or cell nucleus. The progeny of plants so disturbed exhibits abrupt and distinct character changes, not wholly explainable by any regrouping of old characters. The evening primrose, *Oenothera lamarckiana*, carried from the New World to the Old, was thrown by the change into some state of nuclear instability. Three varieties appeared, each breeding true. Variety gigas has twenty-eight chromosomes instead of the normal fourteen, and has an accompanying structural characteristic, a greatly increased size. Variety semigigas exhibits the triploid number of chromosomes, whilst variety lata has fifteen. Environmental change has been accompanied by nuclear disturbance, an outward sign of which is the changed structure of the individual.

Luther Burbank, experimenting in specific plant crosses, produced entirely new varieties of plants. The union of species of dewberries and raspberries resulted in the primus and phenomenal berries—fruits with new size, colour, texture, and taste characters. These proved to breed true. The plumcot, a cross between plums and an apricot, does not appear to have become fixed.

In nature, combinations of circumstances are known to produce mutants. Darwin, calling them "sports," attached too little importance to them in his view of biological evolution, while De Vries, passing to the other extreme, held that evolution had progressed solely through their instrumentality. Both views have proved narrow. Xerophytes have developed in each way, and, should a complete suite of Western Australian fossils ever be available, some plants will be traceable, step by step, back to their hygrophilous ancestors, whilst others will prove to have assumed drought-resistant characters in an abrupt manner.

One further phase of xerophytism remains to be mentioned, and that is its relationship with plant parasitism. A profusion of cassy-

thas, the Westralian Christmas Tree,[8] the Sandalwood Tree,[9] the Quandong,[10] and Australian Mistletoes,[11] all make our bush a veritable botanic garden of parasitic plants.

This plentitude of parasites in our xerophytic plant assemblages is worthy of note. It may be that the parasitic habit is as much (or perhaps more) due to the aridity of environment as to the stimulus of nitrogen search. The emphasis is still further removed from the nitrogen-seeking stimulus when it is remembered that in Westralian soils the essential soil constituent present in minimum amount is phosphorus—not nitrogen. Of course it may be shown that many of the parasites remove nitrogen containing compounds from their hosts, but this, though now of great importance to the parasite, may be quite a secondary phase of the habit.

Again, in some instances, it may be noticed that a cassytha puts out haustoria at places which are not in contact with any host. The parasitic attack must in these cases be an act innate in the parasite and not dependent on external stimulus. With evidence of such a change having been accomplished, it does not seem right to ascribe the origin of parasitic habits to nitrogen-seeking simply because a parasite may be shown to derive nitrogen from its host.

Thus, although usually regarded only in its nitrogen relationship, plant parasitism in Western Australia possibly originated as a modification capable of adjusting some disparity between water absorption and water loss. The securing of nitrogen would be at first a non-essential concomitant of successful attempts to secure water from better provided neighbours, and the highly specialised parasites exhibit the ultimate developments of a trend of evolution which originated in some stimulus of water relationship.

References to plates.

C. = stomatal cavity.
C.T. = curvature tissue.
Cu. = cuticle.
E. = epidermis.
G.C. = guard cells.
H. = hairs.
L. = lens-like epidermal cells.
M. = mesophyll cells.
M.P. = palisade mesophyll.
M.S. = spongy mesophyll.
Sc. = sclerenchyma.
S.F. = secondary furrows.
S.P. = stomatal pit.
V.B. = vascular bundle.
W.P. = water-storing parenchyma.
X. = entrance to furrow.
Y. = air above leaf becoming enclosed by rolling.
F. = fibres underlying epidermis. (In Plate XVII. layer is almost continuous below stomata.)
Fi = fibres surrounding water-storage tissue.

8. Nuytsia Floribunda. 9. Fusanus Spicatus. 10. Fusanus Acuminatus, 11. Loranthaceæ.

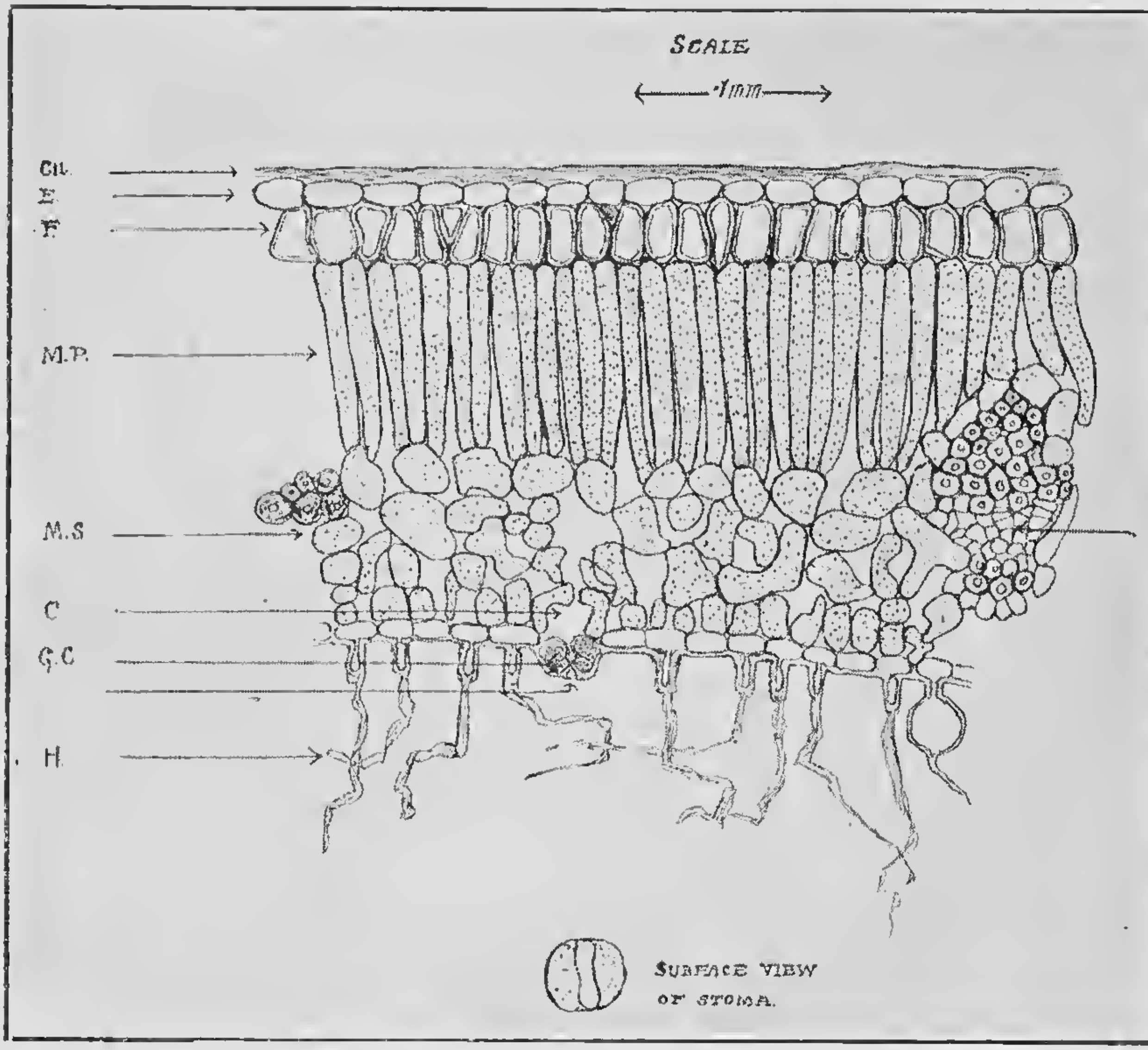

Plate XV., No. 1.—Leaf of Banksia *Attenuata*.

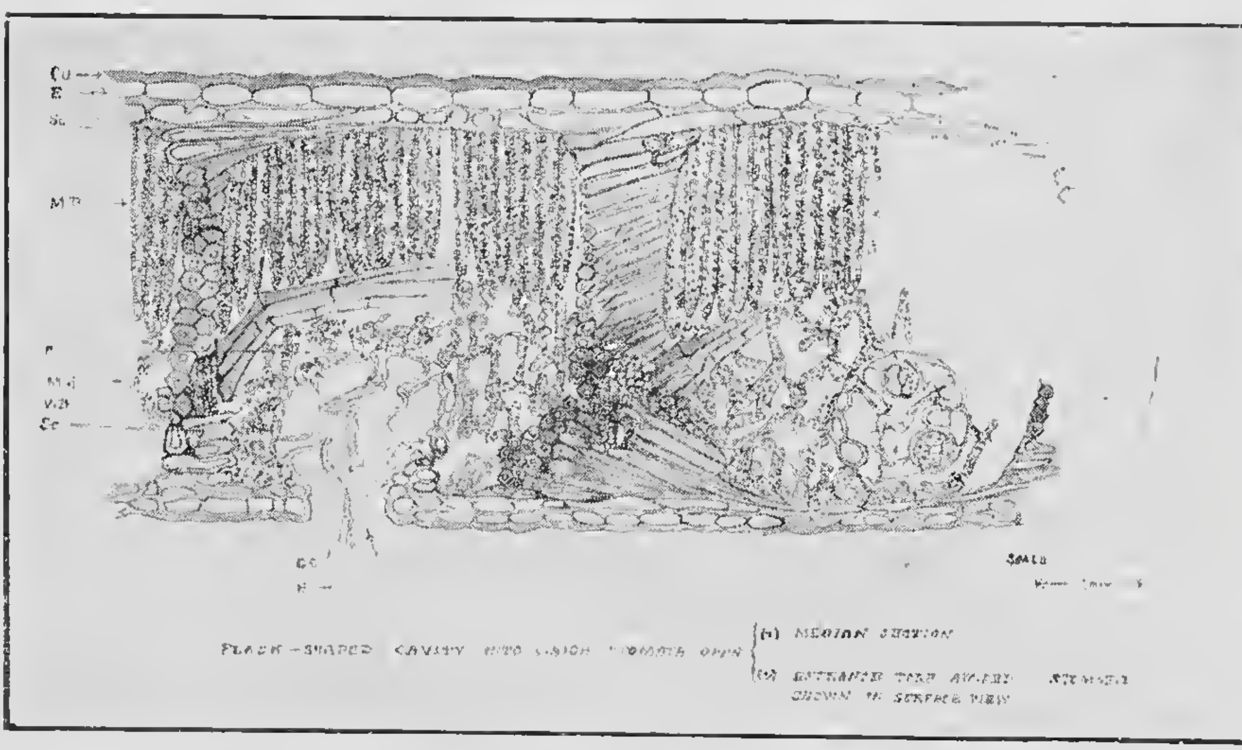

Plate XV., No. 2.—Leaf of *Dryandra Floribunda*.

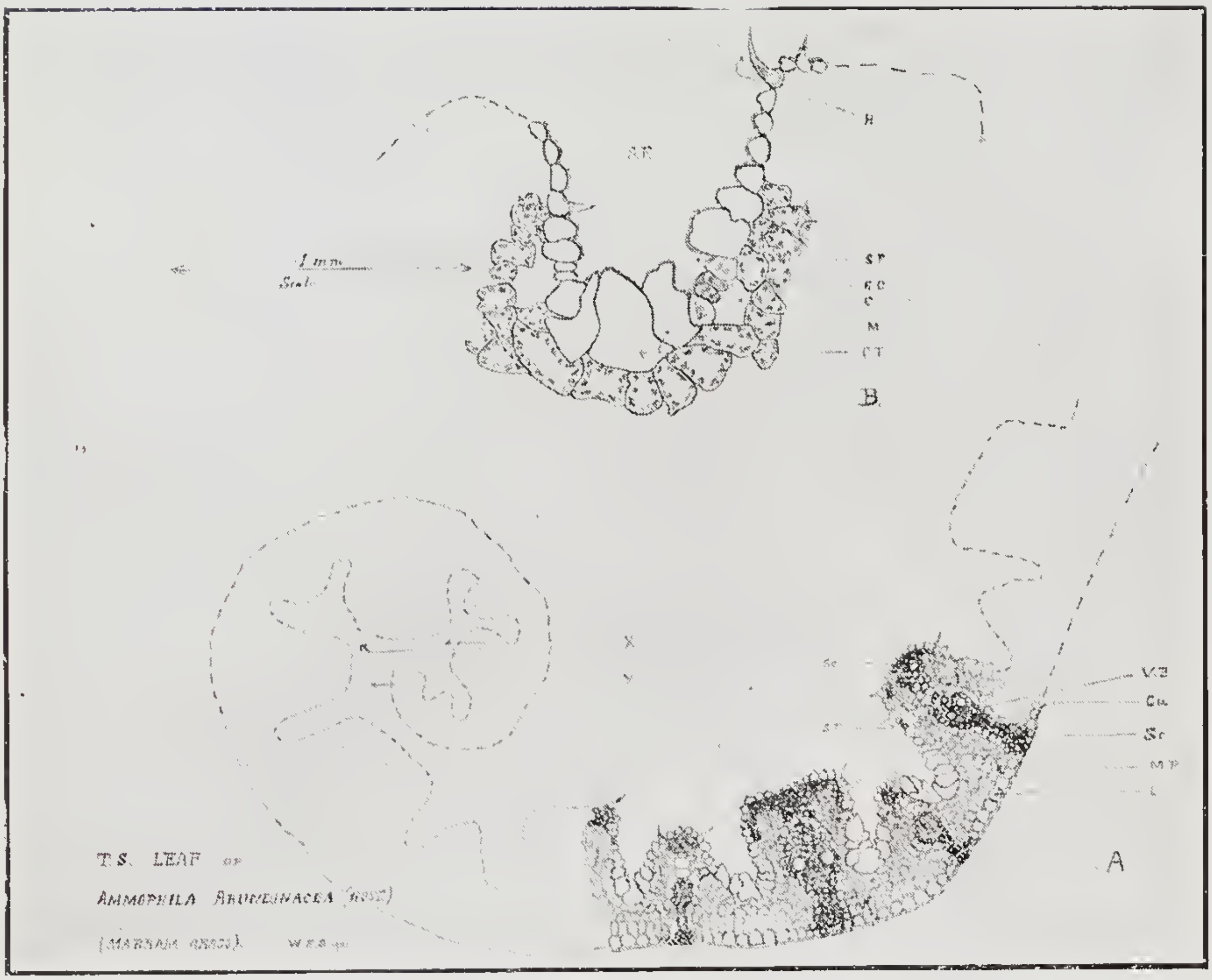

Plate XVI.—Leaf of *Ammophila Arundinacea.*

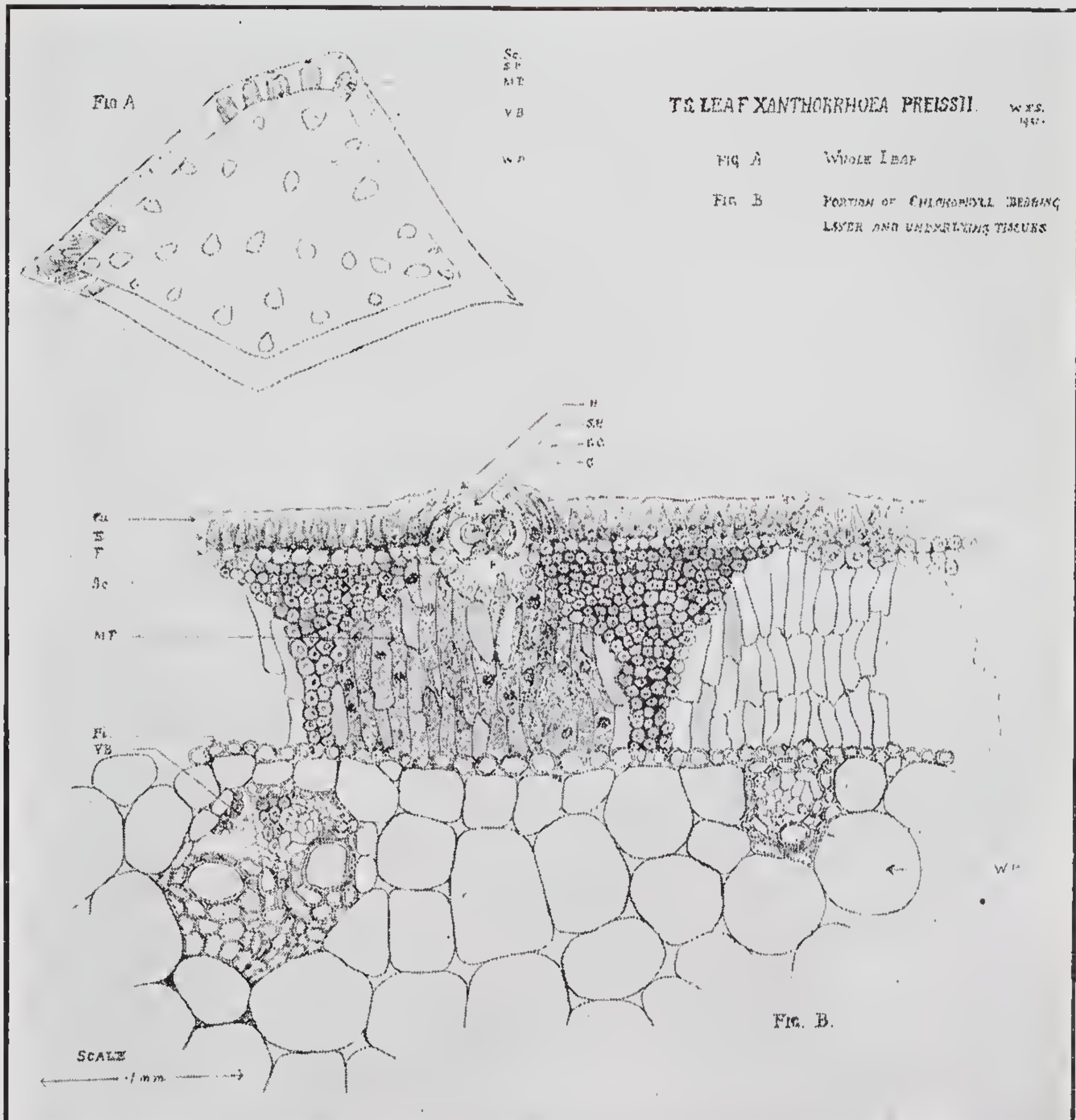

Plate XVII.—Leaf of *Xanthorrhœa Preissii.*

NOTES ON THE TEETH OF NOTOTHERIUM MITCHELLI.

No. 1.—VARIATION IN THE UPPER PERMANENT PREMOLAR OF *NOTOTHERIUM MITCHELLI*, OWEN.

By L. Glauert, W.A. Museum, Perth.

(*Read on* 14*th June*, 1921.*)

The permanent Premolar tooth of diprotodont marsupials, the only replacing number of the dental series, is most important for diagnostic purposes, it alone being sufficient for the determination of many species.

It is therefore of interest to describe a variation noticed among the remains of *Nototherium Mitchelli* collected in the Mammoth Cave, Margaret River, in the extreme South-West of this State. It must be remarked that the associated lower permanent premolars do not show a corresponding range of variation from the type.

The tooth is described by Professor Owen in the following terms:—"The first upper molar (d^3) may be said to be two-lobed, but it is divided in an opposite direction to that in the rest of the series, viz., into an outer and an inner, rather than a front and a back lobe. The working-surface is sub-triangular in form, the angles obtusely rounded, measuring in fore-and-aft extent 1 inch 1 line in the male *Nototherium Mitchelli;* the transverse diameter, posteriorly, is 11 lines.

The outer lobe or division is the chief one, and constitutes the outer two-thirds and the whole fore-and-aft extent of the tooth; the outer side of its base swells out like part of a cingulum or ridge; the summit is subcompressed, and seems to have been trituberculate; the inner and lower divisions consist of a larger hind tubercle and a smaller front one. . . . .; it is implanted by two roots, one behind the other, the posterior being the largest and grooved anteriorly, as if preparatory to further transverse subdivision."†

The Mammoth Cave specimens supply a series of ten upper premolars in all stages of wear, including teeth that have just recently come up into line, as well as others that have been in use for some considerable time.

* By permission of the Trustees of the Museum.

† Phil. Trans. Roy. Soc., 1872, page 67. *See* also Extinct Mamm., Aust., 1877, Vol. I., page 275.

They vary in size, the length antero-posteriorly ranging from 22 m/m to 29 m/m, and the width from 20 m/m to 23 m/m. The tooth is markedly tuberculate, consisting essentially of three external and two internal tubercles or cusps. The anterior external cusp occupies a talon projecting from the main mass of the crown and may be connected with the succeeding external tubercle by a bridge of limited development. The intervening valley is bounded externally and internally by a cingulum, which is more prominent on the lingual face of the crown.

The two posterior external tubercles are more massive than those placed internally and are always united by a bridge, reaching almost to their summits in an unworn tooth and forming a strong external lobe.

The antero-internal cusp is also well developed, being in every case larger than the hind one, not "smaller" as stated by Owen; it is joined to the median external tubercle by a slender sygmoidal ridge which is much less prominent and less massive than that forming the external lobe. With wear this group of connected cusps develops into an "L" shaped mass, of which the "twisted loop of exposed dentine" of Scott † is an extreme form.

The smaller posterior lingual tubercle is variable in size; it may be reduced to a slight swelling on the cingulum enclosing the postero-internal portion of the crown, as described in 1912‡, or it may be developed into a mass attaining about half the altitude of its fellows. It is connected with the anterior lingual cusp by a bridge, usually almost obsolete, but on one specimen a strong internal lobe sloping backwards is formed by the exceptional development of the bridge.

The cusp is also united to the posterior labial tubercle by a weak sinuous connection which varies in extent, being quite distinct on the inner tubercle and on the floor of the valley but splitting up into a number of faint radiating folds on the inner aspect of the posterior external cusp.

Only in one instance, that exhibiting the maximum development of the posterior lingual tubercle and the longitudinal bridge may the tooth be considered to resemble the typical example described by Professor Owen, as quoted above. The presence of this tooth in the collection is taken to indicate that the upper permanent premolar is a variable tooth and that the animals in the South-West had not succeeded in establishing a distinct species or geographical race before they became extinct.

† A monograph of Nototherium Tasmanicum, Geol. Surv. record No. 4, Hobart, Tasmania, 1915, p. 12, and figure.

‡ Glauert. Records W.A. Mus., Vol. I., pl. 2, 1912, p. 41. Pl. vi., fig. 10.

No. 2.—DESCRIPTION OF THE DECIDUOUS PREMOLAR OF *NOTOTHERIUM MITCHELLI*, OWEN.

In marsupials the dental series contains but one replacing tooth—the so-called "permanent premolar." In many of the *Macropodidae* it replaces two teeth, the "milk premolar" and the "milk molar," but as a rule it has but one predecessor, the "milk premolar." The milk premolar of *Thylacynus* is developed and absorbed before the animal is out of the foetal stage, and, in the case of *Phascolomys,* the deciduous tooth is merely vestigeal.

Our knowledge of the dentition of extinct forms is very incomplete; in regard to the *Diprotodontidae* the remarks of Lydekker in 1889,* "So far as we know at present there is no evidence of any tooth change or of the presence of a deciduous pm. 3 in either *Diprotodon* or *Nototherium,*" do not appear to have been questioned or modified by more recent discoveries.

A specimen from the Mammoth Cave, consisting of a small fragment of the right side of the skull of a young individual and including the facial portion from the orbit to the socket of the incisor with the dentition and the anterior portion of the palate is, therefore, of particular interest, because of the light it throws upon the dentition.

The teeth present consist of the deciduous premolar in position but showing no trace of wear, and the posterior molariform tooth, still in its formative cavity, but evidently ready to emerge and take its place in the tooth line.

On account of the swoollen state of the maxilla below the infraorbital foramen, an opening was made in the wall of the socket of the incisor disclosing the presence of an imperfectly formed successor to the milk-premolar. There is therefore no doubt that *Nototherium,* like the majority of the marsupials, possessed a deciduous premolar and a replacing tooth.

The deciduous tooth is triangular, with a prominent crest externally and a well marked tubercle on a distinct talon at the postero-internal angle of the crown; this tubercle is connected with the cusp by an almost obsolete bridge across the floor of the intervening valley, which is closed internally and posteriorly by a strong sinuous cingulum. This ridge ascends the outer cusp anteriorly, gradually merging into the crest, but posteriorly it rises up the hind edge of the cusp forming a distinct prominence in line with the cusp but separated from it by a well marked notch. The highest part of the

* Annals and Magazine of Nat. Hist. (6), Vol. III., No. 14; Feb. 1889, p. 151.

crest is just in front of this notch; from this point the cutting edge slopes convexly downwards until it merges into the cingulum at the anterior angle of the tooth.

The tooth appears to be implanted by two roots, a very small one at the anterior angle and a very massive one posteriorly.

The following measurements have been taken:—

Antero-posterior dimensions	10.5 m/m
External face of crown	10.5 m/m
Internal face of crown	11 m/m
Posterior face of crown	11 m/m

REPORT BY Mr. L. GLAUERT ON THE PROCEEDINGS OF A CONFERENCE "TO DETERMINE WHETHER CERTAIN BIRDS, ETC., SHOULD BE DECLARED VERMIN OR OTHERWISE."

At the March meeting of the Royal Society Mr. J. Clark and I were appointed delegates to attend this Conference. It was held at the Rabbit Branch on March 23rd, 1921. The following persons were present:—

The Hon. C. F. Baxter,	Minister for Agriculture.
Mr. Lane-Poole,	Conservator of Forests.
Mr. Male,	Pastoralists' Association.
Mr. Shallcross,	" "
Mr. Aldrich,	Chief Inspector of Fisheries.
Mr. Hamilton,	Education Department.
Mr. Le Souef,	Director of the Zoo.
Mr. L. Glauert,	W.A. Museum, and Royal Society.
Mr. J. Clark,	Royal Society and Forestry Department
Mr. Newman,	Entomologist, Department of Agriculture.
Mr. A. Crawford,	Chief Inspector of Rabbits.
Mr. Arnold,	Assistant Inspector of Rabbits.
Mr. G. W. Wickens,	Officer in Charge of Fruit Industries.

The subjects dealt with were:—

I.—The Domestic Cat gone Wild:

Mr. Crawford said that he was responsible for having the cat gazetted as protected. There was no doubt cats did a great deal of destruction, and in certain districts were responsible for keeping the rabbits down. For a good many years past he had noticed that many of the native birds had practically disappeared, and he had very serious doubts as to the advisability of protecting the domestic cat. He referred to the great destruction that was going on in the mulga in the Upper Murchison and Gascoyne. It appeared to him that it was due to a beetle that bored into the roots. He had had some roots examined and in every case there were or had been "bardies" in them. Formerly the natives had been the principal check, but they had disappeared. Other checks were the butcher-birds, magpies, crows, etc. Most of these were now being killed by cats, as also were the other insectivorous birds, ground larks, pipits, etc., which were being destroyed wholesale.

The conclusion he had come to was that, though the cat may do a considerable amount of good in the destruction of rabbits, the evil it did was far greater. He thought that if the continual decrease, and even extermination, of our insectivorous birds continued, the insect pests would become quite as bad as the rabbit.

Mr. Clark confirmed Mr. Crawford's remarks regarding the destruction of the big mulga.

Messrs. Newman, Le Souef, Aldrich, and Hamilton joined in the discussion.

The motion "That the Domestic Cat gone wild be declared vermin" was proposed by Mr. Clark, seconded by Mr. Le Souef, and carried.

II.—Crows, including Ravens:

Mr. Crawford said he had received a large number of applications from Roads Boards and Vermin Boards and from private individuals asking that crows should be declared vermin. This, however, had not been done because he thought that the little damage the crow did was not worth taking into consideration compared with the great amount of good it did. Investigation had shown it to be one of the most valuable insectivorous birds of Western New South Wales. It was an important factor in the destruction of blowfly maggots and carrion.

Messrs. Newman, Aldrich, Glauert, Male, Hamilton and Le Souef confirmed and extended Mr. Crawford's remarks, Mr. Male adding that the crow was valuable in picking tick off cattle. As far as West Kimberley district was concerned he thought that crows should be protected.

The motion "That the Crow be placed on the Game List" was proposed by Mr. Crawford, seconded by Mr. Glauert, and carried.

Mr. Glauert pointed out that if a bird was placed on the Game List it did not necessarily mean that it was protected in every part of the State throughout the year. If the crow were simply placed on the Game List it would still be possible to approach the Department and have it protected for, say, six or nine months of the year.

Mr. Aldrich said that if in a particular district the inhabitants wanted to destroy crows they could put in an application for permission to do so.

III.—Wallabies and Tammars:

Mr. Crawford said that a great number of complaints had been received from the Angusta, Denmark, and Manjimup districts, and also from the South-West District Vermin Board, but

action could not be taken as the Fisheries Department declined to declare wallabies vermin. For many years the country between Denmark and Yallingup had been the principal breeding ground of the dingo. The Department had taken extreme measures against dingoes during the last two or three years, and had destroyed some five or six thousand. Dingoes, which were a natural check on the wallabies and tammars, had been removed, and the latter were now increasing enormously. In many places it was impossible to grow vegetables and potatoes, and in the drier time of the year the wallabies bark the fruit trees.

Mr. Glauert pointed out that there were various species of wallabies, and suggested that steps be taken to identify the harmful species, so that those not responsible for the damage might escape destruction.

Messrs. Crawford, Wickens, and Le Souef continued the discussion, and Mr. Aldrich added that, if the desire was to declare wallabies vermin throughout the State, he would offer strong opposition. He considered that if the marsupials were exterminated the dingo would become a bigger menace than ever.

After Mr. Male and Mr. Crawford had made further remarks, the motion "That Wallabies and Tammars be declared vermin in certain districts, these districts to be defined by the Chief Inspector of Fisheries and the Chief Inspector of Rabbits," moved by Mr. Crawford and second by Mr. Wickens, was carried.

IV.—Silver Eyes:

Mr. Crawford said that various Farmers' Associations and Boards had asked that silver eyes be declared vermin. Up to date he had not done so. Silver Eyes did a lot of damage to soft fruits at certain times of the year, but during the rest of the year they were almost entirely insectivorous. He did not therefore feel justified in declaring them vermin.

After the matter had been discussed by Messrs. Aldrich, Le Souef, Wickens and Clark, it was moved by Mr. Hamilton and seconded by Mr. Glauert "That no action be taken in regard to Silver Eyes at present, and that the stomachs of Silver Eyes should be examined for, say, a year, so that a fairly accurate account of the food supply of this particular species might be given." This was carried.

V.—Eagle-Hawks or Wedge-tailed Eagles:

Mr. Crawford said that eagle-hawks had been declared vermin some time ago. He met some members of the R.A.O.U. recently, the majority of whom said it was a mistake to have the eagle-hawks declared vermin.

Mr. Glauert proposed, and Mr. Le Souef seconded, "That the Eagle-Hawk be taken off the Vermin List."

After an animated discussion it was moved by Mr. Hamilton and seconded by Mr. Clark, "That Eagle-Hawks be allowed to remain on the Vermin List, and if possible further inquiries be made regarding their usefulness." This was carried after the previous motion had been withdrawn.

VI.—Parrots (the Twenty-eight and the W.A. Rosella or Yellow-cheeked Parrokeet):

Mr. Crawford said a good many people had written about these parrots.

Mr. Glauert was of opinion that during the season of the year when there were no soft fruits these parrots did good by eating the seeds of weeds, etc.

After a discussion, in which Messrs. Crawford, Wickens, Male and Hamilton joined, it was moved by Mr. Crawford, and seconded by Mr. Wickens, "That the Twenty-eight Parrot and the Yellow-cheeked Parrokeet (otherwise known as the West Australian Rosella) be declared vermin." Carried.

VII.—Goanna or Giant Lizard:

Mr. Aldrich said he was responsible for protecting the goanna by adding it to the Game List.

Mr. Crawford gave instances of finding four to six rabbits inside a goanna. He stated also that the bob-tailed lizard should be protected as it ate a great many insects.

Moved by Mr. Glauert, seconded by Mr. Clark, "That Goannas be protected." Carried.

VIII.—Butcher-birds and Squeakers (already protected):

Mr. Aldrich said that the butcher-bird was included in the Game Act.

Messrs. Wickens, Newman, Glauert, Aldrich and Hamilton joined in the discussion.

Moved by Mr. Clark, seconded by Mr. Glauert, "That the matter be left as it stands pending further investigations." Carried.

IX.—Doves:

Mr. Crawford said that doves, in and around Perth, were regular garbage eaters.

After a slight discussion it was decided to take no action.

X.—Emus:

Mr. Le Souef said that emus spread the zamia palm seeds in all directions, resulting in the poisoning of cattle.

A short discussion took place. Moved by Mr. Glauert, and seconded by Mr. Newman, "That the matter of the utility of the Emu be investigated." Carried.

Mr. Clark said that there were two or three questions untouched. It would be a good thing if the representatives could meet again to go further into the various subjects. Many things could be investigated in the meantime. At the end of 12 months, no doubt, it would be possible to speak definitely on many of the items brought before the conference. It was no good investigating a matter unless a committee or the whole of the conference sat frequently to deal with the work done.

Mr. Male considered the suggestion a good one. He thought that much good might be done if a recommendation were made to the Minister to make the conference a more or less permanent body, to meet at intervals. Committees could be appointed to conduct definite inquiries.

Mr. Glauert recommended the formation of a small committee to undertake the investigation of the stomach contents of birds. He was of opinion that it could be undertaken by members of the Conference. Mr. Newman and Mr. Clark could identify the insects and supply all information regarding them, and any information desired as to the identity of birds, etc., could be obtained from the Museum.

Mr. Hamilton said he was heartily in accord with the views of Mr. Clark and Mr. Glauert. There were men in Western Australia capable of doing very good work in these directions, and who were sufficiently enthusiastic to give a portion of their time to it. As settlement progressed we would find that these problems became more and more important. He thought a recommendation should be made to the Minister to form some kind of advisory body to assist in working out problems of this nature.

Mr. Aldrich supported Mr. Hamilton. He considered that a series of investigations should be carried out, extending over a considerable time.

The Hon. Mr. Baxter said first of all he wished to thank the gentlemen present who had come forward and made the conference such a success. In regard to the wild cat, they had come to a definite conclusion which would be helpful. They had supported the Department in the stand taken in regard to the goanna. He thought the Conference had been a very valuable one and trusted it was not going to be the last. Regarding the committee which

had been suggested, he welcomed the proposal, but considered that they should go a little further and decide upon the constitution of the committee that day. He was quite prepared to recognise the committee. He trusted that the members of the Conference had enjoyed the meeting as well as he had.

Mr. A. Male said that after hearing Mr. Baxter's remarks he thought that Mr. Clark's motion should be made a definite resolution, and that names for the proposed committee should be suggested.

It was moved by Mr. Hamilton, and seconded by Mr. Glauert, "That a small Committee be appointed, with power to add to their number, for the purpose of carrying on investigation work." Carried.

It was moved by Mr. Hamilton, and seconded by Mr. Le Souef, "That the following gentlemen form the Committee to initiate the work of investigation:—Messrs. Crawford, Male, Clark, Aldrich, and Glauert." Carried.

Moved by Mr. Aldrich, seconded by Mr. Crawford, "That Mr. Glauert be appointed convenor." Carried.

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By Authority: Fred. Wm. Simpson, Government Printer, Perth.